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Intelligent Life in Space



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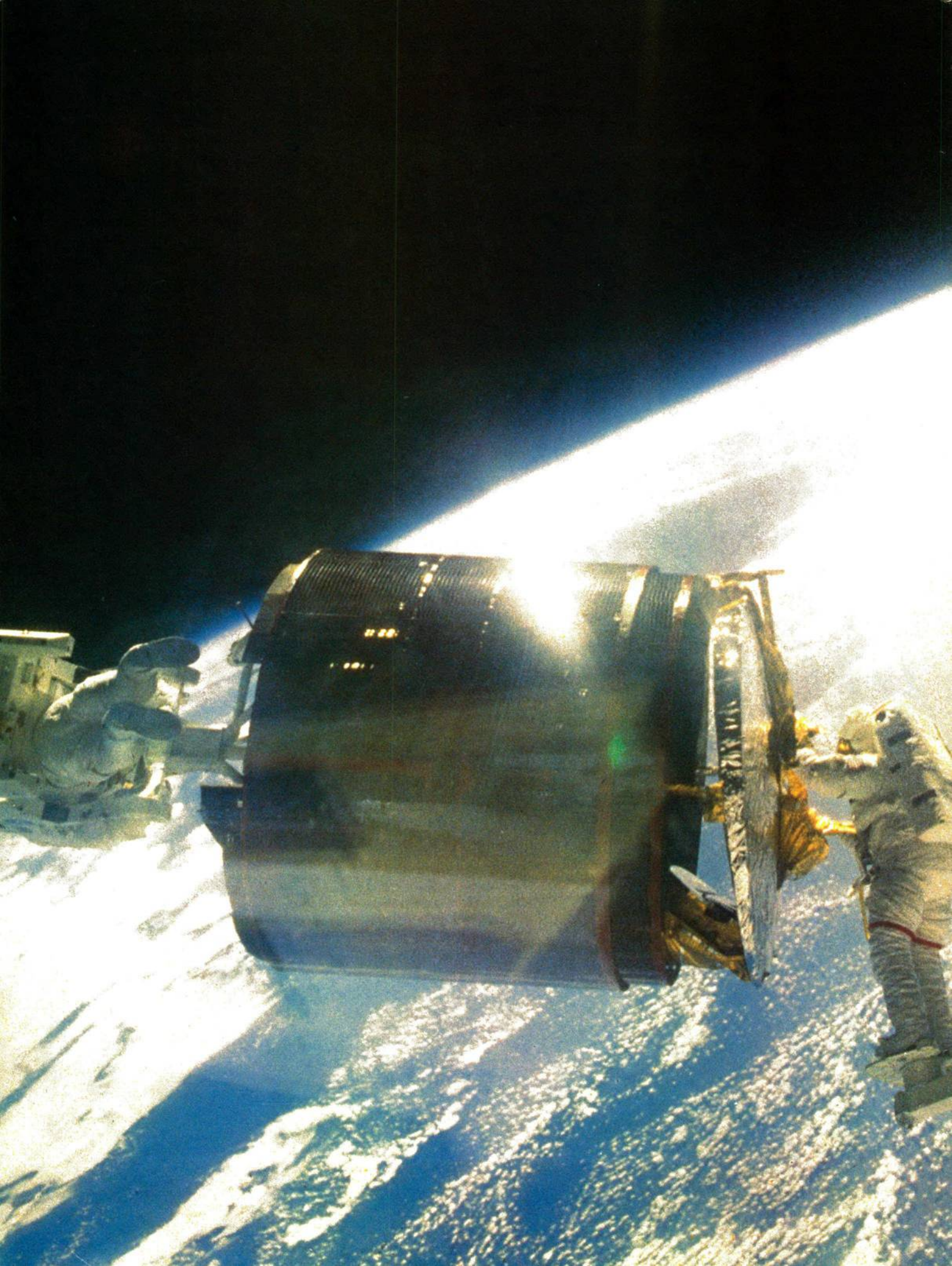
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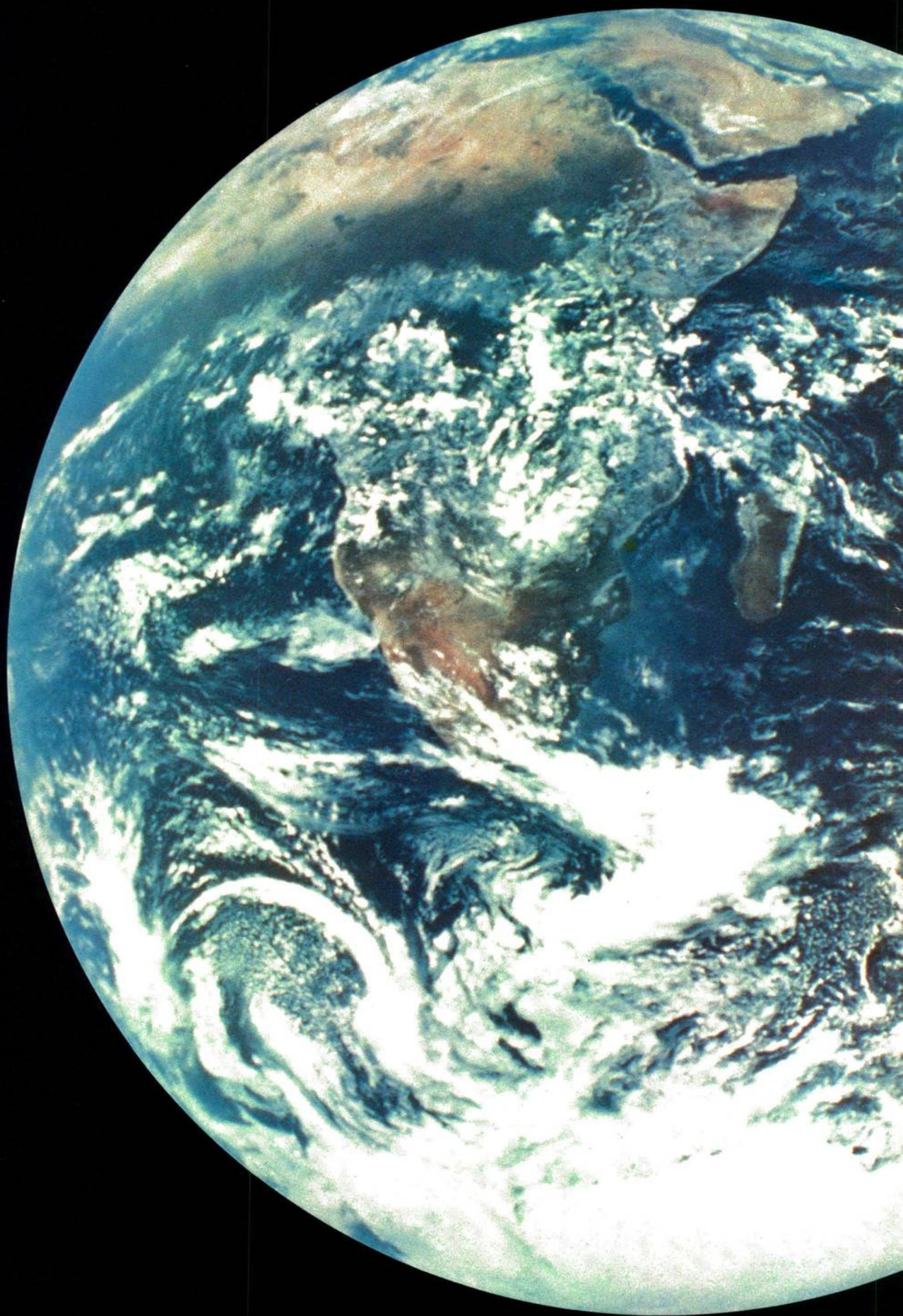
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Cover: Astronaut Dale Gardener recovers the crippled Westar VI satellite for return to Earth. How likely is the chain of events that resulted in human intelligence — and this capability? What is the probability that intelligent beings are doing similar things elsewhere in the universe? These pages: The hallmark of intelligence — cooperation. NASA photographs.

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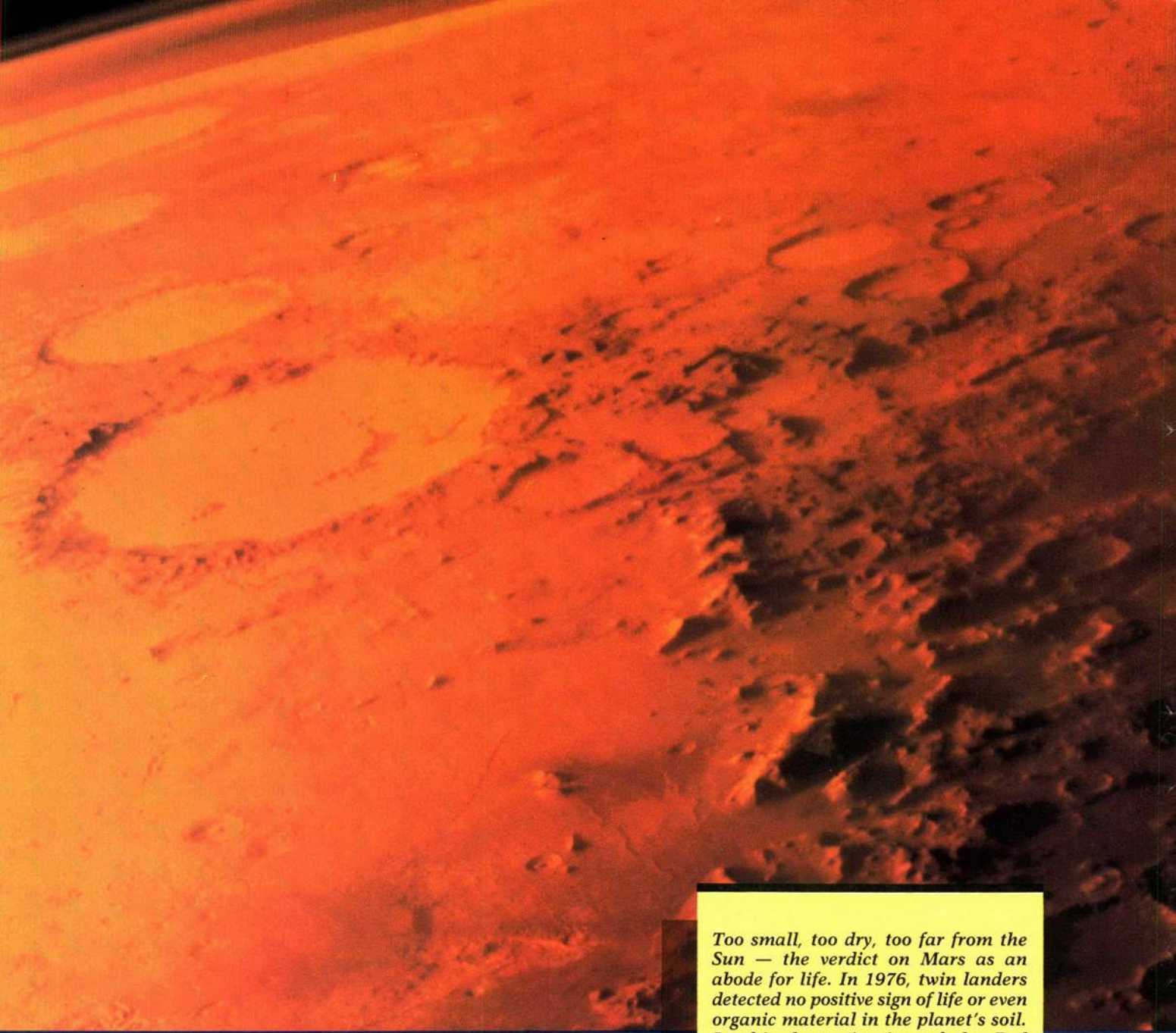


Intelligent Life in Space

by
Edward C. Olson

One's first thoughts about life in the Galaxy often run something like this: Although life is an improbable process, given the enormous number of stars in the Galaxy, many must have suitable planets and some number of them must harbor technological civilizations. This is really an extension of the Copernican principle, "There is nothing special about us," applied to life: "What has happened on Earth can happen elsewhere."

Although questions about extraterrestrial life can be traced far back in recorded history, such questions were only recently framed in the modern context by Carl Sagan and I.S. Shklovskii in their 1966 book, *Intelligent Life in the Universe*. Many of us date our interest in the subject from reading this book, which remains through all the intervening years the most provocative. Spurred by their thinking, a conventional wisdom has evolved to predict N — the number of technological, communicating civilizations now in the galaxy. Many astronomers — and



Too small, too dry, too far from the Sun — the verdict on Mars as an abode for life. In 1976, twin landers detected no positive sign of life or even organic material in the planet's soil. In this dramatic view of the Red Planet from orbit, the rim of the ancient Argyre impact basin and frost-filled craters lie under the thin veil of atmosphere. NASA photo.

a few biologists — have expressed differing degrees of optimism about N , with values ranging from 1 to 10^6 .

The Drake Equation

The Drake equation, sometimes called the Green Bank equation, predicts N . It includes explicitly many of the factors that help to fix N and defines N as the product of a series of probabilities:

$$N = R \cdot f_G \cdot n_{\text{CHZ}} \cdot f_L \cdot f_i \cdot f_T \cdot L$$

where R is rate of star formation in stars per year, f_G the fraction of those stars that are single and near spectral type G (widely believed to be the only stars capable of supporting advanced organisms on surrounding planets), n_{CHZ} is the number of planets in the continuously habitable zone per G star, f_L is the fraction of those planets on which life begins, f_i is the fraction of life-bearing planets that produce cognitive intelligence, f_T is the fraction of intelligent civilizations that develop both

the technology and desire for interstellar communication, and L is the lifetime of this communicative state in years.

If we adopt for these quantities the numbers 10, 0.1, 0.2, 0.5, 1.0, and 1.0 — roughly the canonical “optimistic” estimates — we find $N = 0.1 \cdot L$. For a technological culture that remains active for one million years, N is 100,000. The probability of success in a search for extraterrestrial intelligence therefore seems to be encouragingly high. This result can be ramified endlessly by placing ranges or limits on each factor. Some of these estimates will give “pessimistic” results, that is, they place N close to unity (i.e., close to 1). The ability to put numbers, however uncertain they might be, into this equation lends an air of plausibility to the exercise.

Four of the seven terms in the Drake equation are biological. Yet one somehow feels that life, by far the most complex “system” in the known universe, deserves a more complete representation. Those four terms imply chemical, biological, evolutionary, anthropological, and sociological factors of great complexity to which numbers are nearly impossible to apply. The explanation is that the Drake equation was devised by, and is mainly used by, astronomers. As the chemist Richard E. Dickerson remarked, “It is one thing to propose scenarios for the origin of life that might have been; it is another thing entirely to demonstrate that such scenarios are either possible or probable.”

How might we include biology? We will factor the f_i term from the Drake equation into a series of probabilities describing the evolutionary steps (or their extraterrestrial equivalents) necessary for cognitive intelligence. This retains the probabilistic flavor of the original equation, but recognizes that biology plays a pivotal role in creating the final product. Of course, it is easy to misuse such arguments. For example, consider the following 19-digit number string: 53202000041427626-89. The probability of assembling this string by random digit selection is 10^{-19} — yet it is ASTRONOMY’s combined Zip+4 code and telephone number. I do not consider ASTRONOMY specially favored by the deity to have such an overwhelmingly improbable string; to do so would be a flagrant misuse of statistics. This sequence has a perfectly natural evolutionary origin, shrouded in the mists of postal and telephone operations. Similarly, divine intervention cannot be deduced from some highly improbable molecular sequence in, say, a particular protein molecule. So if we factor biological terms into the Drake equation, we must include only those terms describing necessary evolutionary steps. We can — incorrectly — lower N to a vanishingly small number by adding irrelevant probabilities. Perhaps nobody, least of all an astronomer, can specify these steps unambiguously, but it is certainly worth trying.

Biological Considerations for the Drake Equation

Consider first f_L , the probability that life will appear on a favorable planet. Certainly, the fact that some “life-precursor” organic molecules have been observed in highly improbable places, like interstellar molecular clouds and carbonaceous meteorites, makes their synthesis on planetary surfaces all the more plausible. Several decades of experience with Miller-Urey type experiments assures us that even under the mildly reducing conditions now regarded as probable in the early terrestrial atmosphere, molecules as complex as certain amino acids could form readily.

Some authors have implied that synthesis of amino

acids is a large step toward life. But it depends on one’s frame of reference: by the standards of a stellar interior or the periphery of a black hole, such a statement may be true. Relative to a chemistry laboratory or a planetary surface, such a statement is just as surely false. Harold Klein has remarked: “The early steps in this process of chemical evolution [of life] are becoming fairly well understood, but the critical step in the formation of life, namely, the origin, the *actual* origin of a replicating system, is still very, very far away.” Yet in 1966, Sagan wrote: “The laboratory synthesis of life, at least in the sense of a molecular system *capable* of evolution by natural selection, may be proved in a decade.”

On this point, the astronomers must yield to the chemists. If laboratory experiments cannot yet give a value for f_L , what does the geological record show?

The micro-fossil record suggests that primitive cells were present in the oceans about 3.5 billion years ago. Some biologists have argued from chemical evidence that life already existed when the first sedimentary rocks were laid down about 3.8 billion years ago. In other words, life was present within a billion years or less of Earth’s formation. Does this fact not suggest that f_L is close to unity? Perhaps. However, biologist Leonard Ornstein has argued, from life’s exclusive use of L-symmetry molecules, it originated only *once* on Earth, and that from a single event no statistical conclusions can be drawn. That is, f_L

“The evolutionary process is more subtle than the operation of some law of nature which unfailingly produces complex intelligent creatures.”

could be unity, but it could also be any value down to the infinitesimal. Ornstein likes the value 10^{-6} .

Other biologists have been less pessimistic, so we’ll accept a non-infinitesimal value for f_L — but keep Ornstein’s caveat in mind. If the argument developed below is correct, it may not matter.

With f_i , the probability that life evolves to cognitive intelligence, we face questions of biological evolution. Our only guide is terrestrial evolution as revealed in the fossil record of sedimentary rocks. Even a nonspecialist’s reading of this record uncovers a remarkable sequence of biological “inventions” strung in series through geological time. If any one of these inventions had failed to occur, life would have evolved organisms radically different from those now present on Earth.

Biologists repeatedly warn us that evolution is unique and, in detail, nonrepeatable. Yet we sometimes see statements in articles and books on extraterrestrial life asserting that evolution by natural selection tends to produce more complex species of life, that it favors intelligence, that intelligence has survival value, and that if *Homo sapiens* fails, natural selection would again evolve intelligent creatures on Earth. Can we not, therefore, be optimistic about life elsewhere?

We might be except that, to a high degree of

probability, these statements are wrong. Natural selection, as it was conceived by Charles Darwin and Alfred Russel Wallace, is a two-step process. It requires *first* essentially random genetic variability resulting from the mixture or recombination of parental genes (in sexual reproduction). *Second*, upon this variability the environment exerts a selective, therefore directed, influence so that the fittest individuals survive to produce offspring of their own.

Natural selection does *only one thing*: it produces organisms better adapted to the local environment. It contains no built-in “self-perfecting” principle that guarantees a particular outcome, such as intelligence. In

Life began in oxygen-free Precambrian time some 3.5 billion years ago, as primitive prokaryotic single-celled organisms (i.e., those lacking a clearly defined nucleus). For about three-quarters of its earthly existence, life remained unicellular. Initially, these cells scavenged for organic molecules that had been synthesized naturally in the environment. Life might have exhausted its food sources in about half a billion years, or in any case failed to evolve significantly, had not anaerobic (oxygen-free) photosynthesis (P) been invented about three billion years ago. This process builds glucose, which is then fermented in a relatively inefficient anaerobic decomposition to furnish the cell's metabolic energy.

Roughly 500 million years later, blue-green algae (cyanobacteria) invented aerobic photosynthesis (PO), which produces oxygen as a by-product. This remains today the energy-producing process used by the green planet world. The oxygen waste product, however, was originally a corrosive poison to organic material. Life had either to develop a tolerance to it, or to be restricted forever to oxygen-free niches. Existing prokaryotic bacteria, descendants from those early times, still display wide sensitivity to oxygen ranging from complete intolerance to complete dependence. The ability to use oxygen in cell metabolism increases the energy yield from glucose by more than an order of magnitude over that of anaerobically fermenting prokaryotes, and so is a decided evolutionary advantage.

The invention of aerobic photosynthesis — with its by-product oxygen — had a profound effect on the Precambrian environment. Oxygen, dissolving in ocean water, converted ferrous iron in solution to insoluble ferric iron, laying down the iron-banded red sediments which have become our main source of iron ore. Once this and other surface oxidation processes went to completion some 2 billion years ago, free oxygen began to accumulate in the atmosphere. The ozone layer formed, protecting the oceans from short wavelength solar ultraviolet radiation. Since condensation of ocean water more than 3.8 billion years ago, that same atmosphere has gradually become depleted in carbon dioxide, originally one of its most abundant components. Dissolved in ocean water, carbon dioxide, as carbonic acid, attacks silicate rock and converts it to carbonate rock. Thus, during the Precambrian, major organic and inorganic processes altered the atmosphere toward its modern composition.

Roughly 1.5 billion years ago, the eukaryotic cell (E) appeared. It is a modern cell with a membrane-bound nucleus containing the genetic material and articulate structures, or organelles, which carry out specialized processes of cell metabolism, respiration, and photosynthesis. According to Lynn Margulis and James Lovelock, the eukaryotic cell resulted from a joining of once-independent prokaryotic bacteria, cooperation among which led to important evolutionary advantages. It was, in a sense, an example of symbiosis in evolution. The invention of sexual reproduction (S) followed half a billion years later and this, through genetic recombination, accelerated the rate of evolution enormously.

Further evolutionary advances awaited the invention of multicellularity, which in turn fueled the “Cambrian explosion” of macro-fossils — the beginning of the classical fossil record — some 600 million years ago. This step required synthesis of new kinds of “sticky proteins” (collagen in animals, extensin in plants) that could unite

Important Biological Inventions

Invention	Mnemonic	Origin (billions of years ago)
Origin of Life		3.5
Anaerobic Photosynthesis	P	3.1
Aerobic Photosynthesis	PO	2.3
Eukaryotic Cells	E	1.4
Sexual Reproduction	S	1.1
New Amino Acids	A	0.9
Multicellularity	MC	0.7
Land Plants	LP	0.4
Land Animals	VL	0.35
First Mammals	M	0.2
Angiosperms	AN	0.12
Bipedalism	BP	0.01
Cognitive Intelligence	CI	0.0001

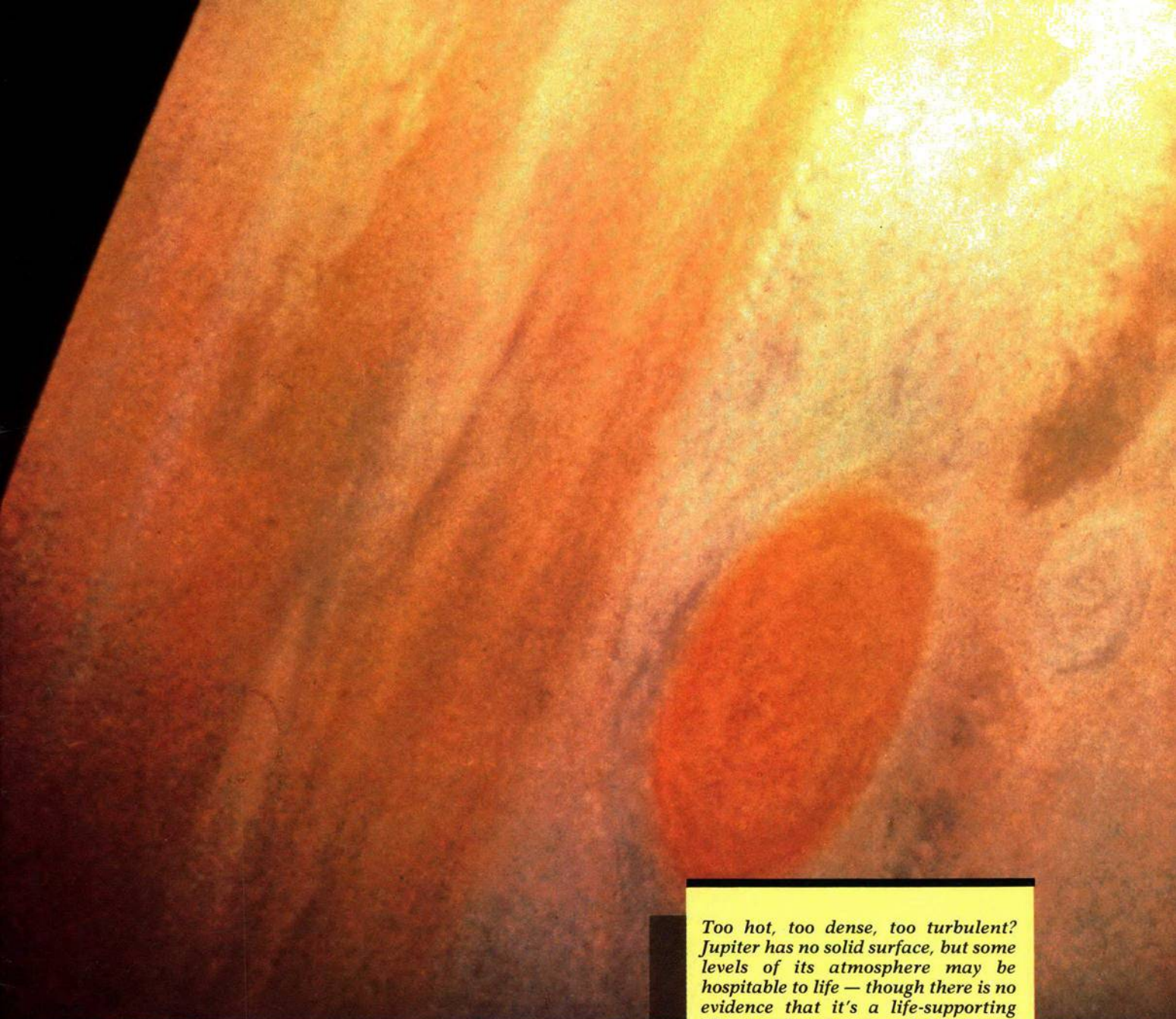
The intervals between major biological inventions seem to have dropped steadily. This table hints that evolutionary acceleration may have begun with the appearance of the eukaryotic cell. After multicellularity, the intervals dropped drastically.

the words of Steven Jay Gould: “We find no story of stately progress, but a world punctuated with periods of mass extinction and rapid origination among long stretches of relative tranquility.” The same author also states: “Evolution by natural selection is no more than tracking of . . . changing environments by differential preservation of organisms better designed to live in them: hair on a mammoth is not progressive in any cosmic sense.”

A casual reading of the fossil record does show that the most advanced animals, the large mammals, did diversify last — after extinction of the dinosaurs. But mammals, including primates, would never have existed had not a complex and diverse environment, with its associated food chain, evolved to support them. Hence, the evolutionary process is more subtle than the operation of some law of nature which unfailingly generates complex intelligent creatures. We need to examine terrestrial evolution to face this problem more clearly.

Factoring f_i

The step-wise evolution of intelligence on Earth suggests that the overall term f_i can be factored to show explicitly the major “biological inventions” (or their extraterrestrial equivalents) in an expanded Drake equation. We will review these inventions briefly and assign to each a term in the equation.

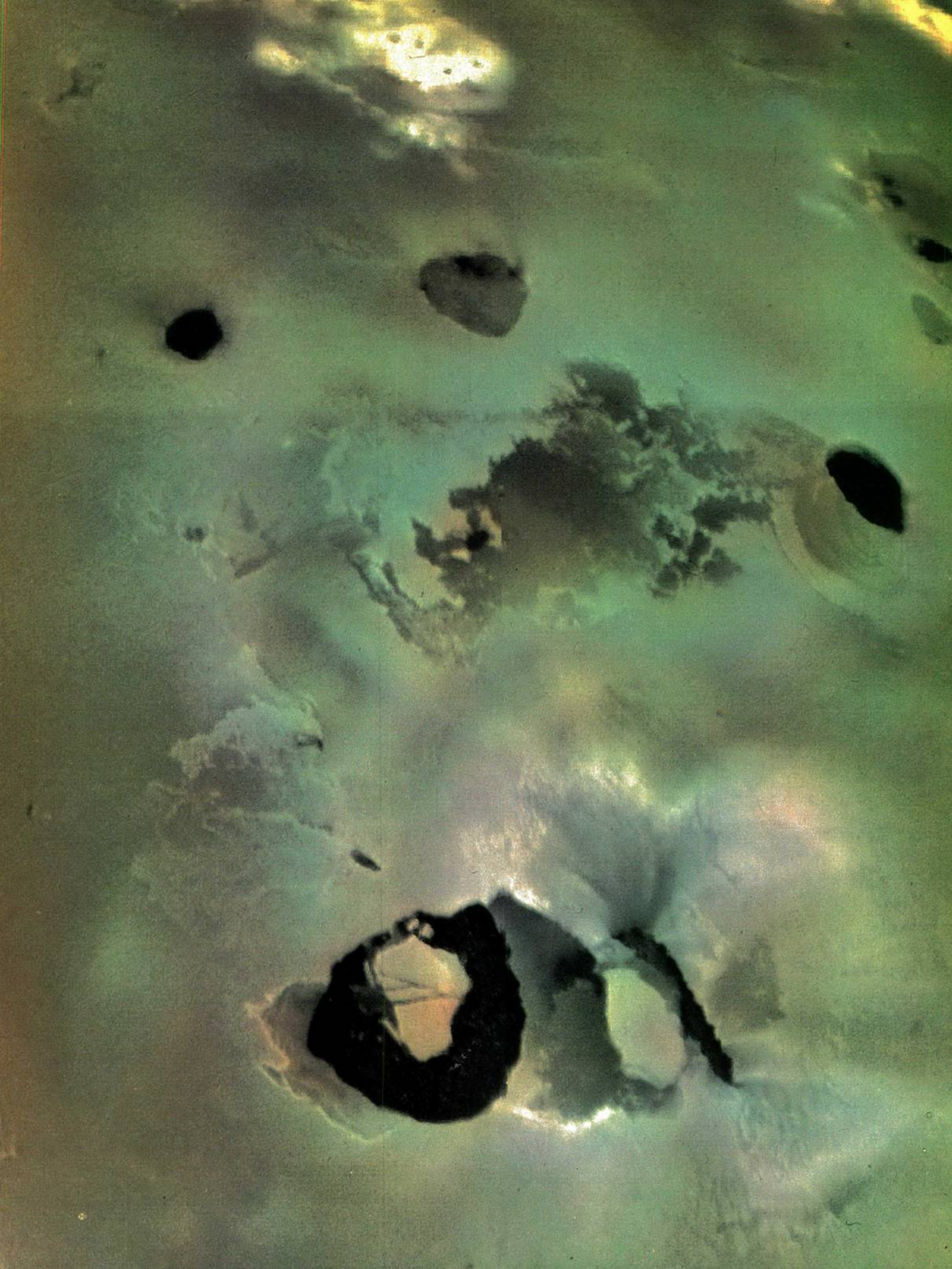


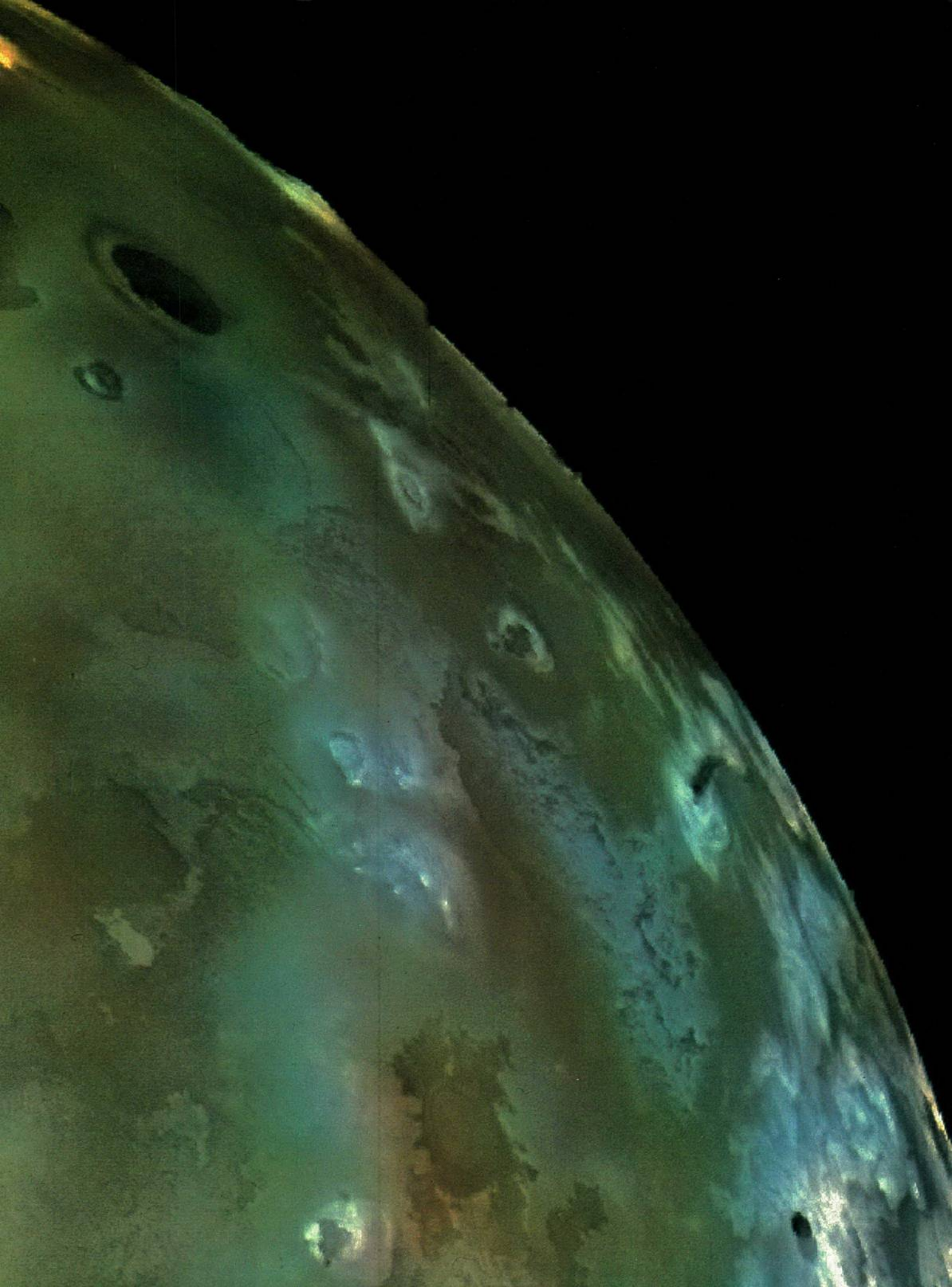
eukaryotic cells to build large structures.

But their manufacture first required cells to invent two new amino acids which are encoded in the genetic molecule DNA, and which further require oxygen for their synthesis. We take the invention of these new amino acids (A) as the key to multicellularity. Once these new proteins became available, multicellular plants and animals (MC) “quickly” originated independently many times; one might say that multicellular organisms were poised in the wings awaiting the appearance of the collagen-extensin protein family. As Kenneth M. Towle has written: “The development of entirely new amino acids was the real key to opening the way for complex multicellularity . . . [without these new amino acids] . . . Earth would probably still be dominated, as it was for much of the Precambrian, by prokaryotes and smaller eucaryotes, and [macro-] fossils would be rare everywhere.” According to Gould, the Cambrian explosion followed a simple organic growth pattern: initially, an exponential growth of new organisms,

Too hot, too dense, too turbulent? Jupiter has no solid surface, but some levels of its atmosphere may be hospitable to life — though there is no evidence that it's a life-supporting planet. What fraction of the planets in our Galaxy are giants similar to Jupiter? Pioneer 11's photopolarimeter scanned this image of Jupiter in 1974 — over 10 years ago. NASA photo.

Overleaf: The magnificent desolation of Io's surface suggests a galaxy full of planets too harsh for life. Blasted by volcanic eruptions and bombarded by high-energy radiation, the chemical precursors of living things would never last long enough to undergo the first transformation. The large dark lava lake lies near the volcano Loki Patera in this Voyager spacecraft image. NASA photo.







Stars are born in great clouds of cosmic gas and dust. Around some of those stars circle planets, and on some of those planets conditions are right for life. The question is not whether this happens, for we know it has happened once, but how often it happens. Orion Nebula photo © 1981 by the Anglo-Australian Telescope Board.

followed by a plateau in numbers as the environmental support limits were approached. Once again, it was the environment, and not some intrinsic property of natural selection, that determined the outcome.

These five Precambrian biological inventions, from anaerobic photosynthesis to the manufacture of new amino acids, were all necessary to evolution. Would something like them occur on other planets? If, as many have suggested, the microspheres of thermal protenoids and the tiny polymer-rich coacervate droplets produced in laboratory experiments really are "analogies to life," then it may be natural for life elsewhere to appear first as primitive single-celled scavengers. The conversion to autotrophism (food synthesis) also seems essential for further survival and evolution, and the obvious energy source would be light from the central star. Some kind of photosynthesis would, therefore, have to evolve. Efficient single- (and multi-) celled organisms require oxygen in their metabolism, so aerobic photosynthesis

Overleaf: "They've gotta be out there somewhere!" Astronomers have concentrated on the astronomical odds — but what are the biological odds that among the billions and billions of stars in the Milky Way Galaxy we'll find thinking beings? Great Sagittarius Starcloud, Lick Observatory photograph.



also seems a necessary step in the evolution of complex energetic lifeforms. A means to stick cells together would have to be found to make large organisms. Thus, we may be reasonably sure that these five steps or their equivalents would have to occur along the path to technological civilizations. These were laborious inventions, each taking, in round numbers, half a billion years to achieve. One can hardly say that they were either pre-ordained or even particularly likely to occur in another setting.

Beyond this point, complex multicellular forms quickly traveled specific and nonrepeatable evolutionary paths in a way impossible to generalize to other planets. Through the structure of the DNA molecule, modern biochemistry has opened an enormous range of potential genetic variability. Living flesh has become almost infinitely malleable; we can only trace the terrestrial example and assume that some approximate equivalent can occur elsewhere.

Through the Cambrian explosion, most life remained ocean-bound, deriving its oxygen for metabolism directly from water solution. Advanced organisms on Earth are all air-breathers, including the cetaceans which evolved from land-dwelling mammals and returned to the sea. At some point, life *had* to move ashore. This happened for vascular plants some 400 million years ago during the Silurian epoch. With this invasion, plants faced difficulties of mechanical support (having lost their marine buoyancy) and exposure to near-ultraviolet solar radiation. The solution was the biological invention of lignin (LP), which in various types of plant cells solved these problems and made the floral land invasion possible.

Similar challenges of mechanical support and a critical need for respiratory oxygen were faced in the Devonian land invasion by animals. The former requirement was met by the evolution of the vertebrates: animals with backbones. Backbones presumably conferred an advantage on organisms swimming upstream against the currents of nutrient-rich waters from streams emptying into the oceans. For oxygen, the first amphibians developed an accessory lung for direct breathing. These two inventions (VL) were the key to the animal land invasion. This transition was clearly pivotal in the development of all higher animals.

Describing this invention many years ago, Loren Eiseley wrote: "It was not the magnificent march through the breakers and up the cliffs that we fondly imagine. It was a stealthy advance made in suffocation and terror, amidst the leaching bite of chemical discomfort. It was made by the failures of the sea . . . [and] . . . seems to have been largely determined by the inexorable crowding of enemies and by the retreat further and further into marginal situations where the oxygen supply was depleted."

Thus life, driven to dire extremes, may evolve its most significant changes to bestow them on creatures who may seem, temporarily, to be evolutionary failures. Fewer marine competitors, a smaller land area, less vigorous ocean tides, or any one of a large number of environmental particulars could have delayed — even aborted — this crucial step.

Throughout Carboniferous time, land-based organisms and environments diversified together. During the formation of the "supercontinent" of Pangaea in the late Permian, the loss of coastal oceanic habitat may have triggered a major marine extinction. The Mesozoic era (225 to 70 million years ago) saw the first mammals and

birds and encompassed the Age of Dinosaurs; it ended with their much-debated demise. One of the key events of the Mesozoic was the rise of the angiosperms (AN), flowering plants whose origin Darwin termed an "abominable mystery." By geological standards, it was an explosive radiation that carried implications for all future life. With flowering plants came nectars and pollens, insect pollination, and — above all — fruits and seeds which concentrated food energy to previously unknown degrees.

With the end of dinosaurs, mammals (until then small rodent-like creatures) were free to explore their biological future powered by the fruits and seeds of the angiosperms. Among evolving warm-blooded mammals were the tree-dwelling primates (T). This crucial form could exploit an ecological niche which made complex and specific demands on the organism. Effective adaptation to the tree environment produced stereoscopic vision and prehensile (grasping) hands. With later environmental changes, in particular the decline of the forest environment, the great apes — at least those individuals who survived and passed on their genes — "descended from the trees" some 10 million years ago.

Of the differing forms of these related primates (chimp, gorilla, orangutan), only protohumans became bipedal (BP), perhaps four million years ago. Bipedalism is now known to predate the use of stone tools and the rapid increase in brain size that carried evolving hominids to truly human intelligence. The reasons for bipedalism have been much debated, but according to Owen Lovejoy they must have been part of an overall survival strategy. Related primates which produce a single offspring once every four to six years (the so-called "K-reproductive strategy") are hastening toward extinction even without human predation. Lovejoy also believes that bipedalism brought with it an increased attraction between the sexes, and thus more persistent mating.

Bipedalism also freed the arms, allowing food gathering, and carrying of babies unable to hang on by themselves. But both food gathering and infant care *also* depended on the earlier prehensile adaptation to arboreal life. And from the bipedal innovation, which among the great apes is unique to the hominids, flowed everything else. In Lovejoy's words: "It was sheer luck that their ability to stand up and use their hands led to a later development of tools and the creation of a culture, and a still larger brain . . . But all those things came afterward, as a by-product of what it was really all about — a better reproductive strategy."

The evolution of cognitive intelligence (CI), oversimplified here as a single step, probably blended many factors, some unknown. One obvious point, which we can check in the fossil record, is the use and manufacture of stone tools. Yet while hominids were confined to the tropics, advances were relatively slow. As Bernard Campbell points out, evolution accelerated with the development of fire and the hominid migration to northern temperate latitudes.

Our present epoch, the Pleistocene, has so far seen four major northern glaciations and a mass extinction of many large animals. It was only in facing adverse conditions, equipped with bodies physically weak by contemporary animal standards, that the hominids survived and evolved to *Homo sapiens*.

We can picture protohumans slowly being pushed northward, perhaps encountering animals streaming away





from the encroaching glaciers. Possibly for the first time, hunting large animals became necessary for survival; those individuals not disposed to cooperate did not live to reproduce. As fire, clothing, and protection from the elements became absolute necessities, these new demands on the hominid brain became prerequisites to life — and reproduction. (Possibly, too, the first astronomical observations began, watching stars to anticipate the changing seasons.)

The human brain appears to have arisen in part because it improved the chances of living through a very specific sequence of environmental changes. It does not seem likely that the evolution of intelligence was a sure thing. A harsher environment could have eradicated the hominids; an easier life might have favored factors other than cognitive intelligence. With all due respect to its occurrence here, the probability of its occurrence elsewhere, P_{cl} , is not likely to be even close to unity.

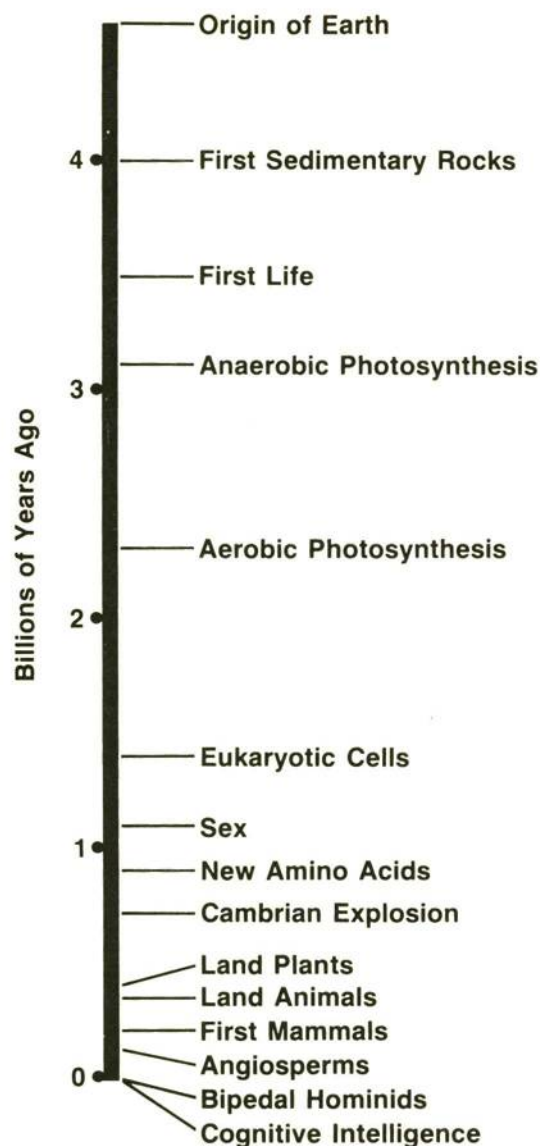
So, to the five Precambrian factors in life's evolution, we can add at least six pivotal developments during Phanerozoic time. These eleven steps are the minimum obvious ones; more knowledgeable writers would add to this list, and expand upon the simple arguments presented here. In the end, it seems almost miraculous that *Homo sapiens* managed to evolve on Earth at all.

Before trying to assess the implications of these arguments to the calculation of N , we return briefly to the question of the survival value of intelligence. Following Lovejoy, we will select two of the most intelligent mammalian orders: the Proboscids (including elephants and related extinct species like the mammoth) and the Primates. The Proboscids, with large brain-to-body ratios, originated in the early Cenozoic era. They began a long decline in the Miocene epoch, failing to compete successfully against large but less intelligent animals. Of this large radiation only two species remain today; intelligence has not served these mammals well. In the case of the Primates, with the single exception of the hominids, all of the great apes are headed for extinction, mired in the K reproductive strategy.

One can scarcely conclude from available data that intelligence generally *implies* survival. This conclusion surprises us, probably because intelligence has such a high survival value to humans, but it does not necessarily aid animal survival in general. The implications for N are not optimistic.

Consider bipedalism. It was a crucial invention for the hominids. But no single invention suffices — several dinosaurs invented bipedalism and passed it on to the birds. The kangaroo, a marsupial mammal, is also bipedal, but it has brought him little in return. For the hominids, the prehensile grasp and stereo vision left over from those swinging days were prerequisites for success. But then, after the bipedal fact, the experiment would have failed had not a continuing sexual attraction been maintained. Thus it is not any one invention, but the sequence of innovations occurring in the right order that is important.

This discussion, as we shall soon see, implies that N is probably very much smaller than one. This does not necessarily imply that life itself is rare in the universe, but that even after life begins on a planet, evolves energy sources, becomes complex — even after all that — communicating across the interstellar void may have low probability. These arguments are of course highly speculative. It may *still* seem possible to take refuge in a Copernican faith — that what happened on Earth could



The twelve major biological inventions and their approximate times of origin. The mean interval between inventions in the Precambrian was approximately half a billion years, while after the Cambrian explosion it dropped to 120 million years — give or take 100 million years.

happen on other selected planets. We have no other worlds as examples of alternative evolution. Or have we?

Loren Eiseley pointed out years ago that, in a sense, we do have such worlds. They are the gifts of continental drift — the “worlds” Australia and South America nearly isolated from major outside influences since the breakup of the Pangaea some 200 million years ago. In Australia, ecological niches high in the food chain are occupied by slow-brained marsupials; there is no hint of the emergence of intelligent mammals like the primates. In South America the isolation has been less complete, but in the case of the South American monkeys: “... things have gone



Beyond our Milky Way, there are other galaxies, each with billions of its own stars. Could we exchange signals with intelligent and communicative beings in the Large Magellanic Cloud, a satellite of our own Galaxy? Technically it might be possible — but we would have to wait 300,000 years for a reply. Photo © 1978 by the U.K. Schmidt Telescope Unit.

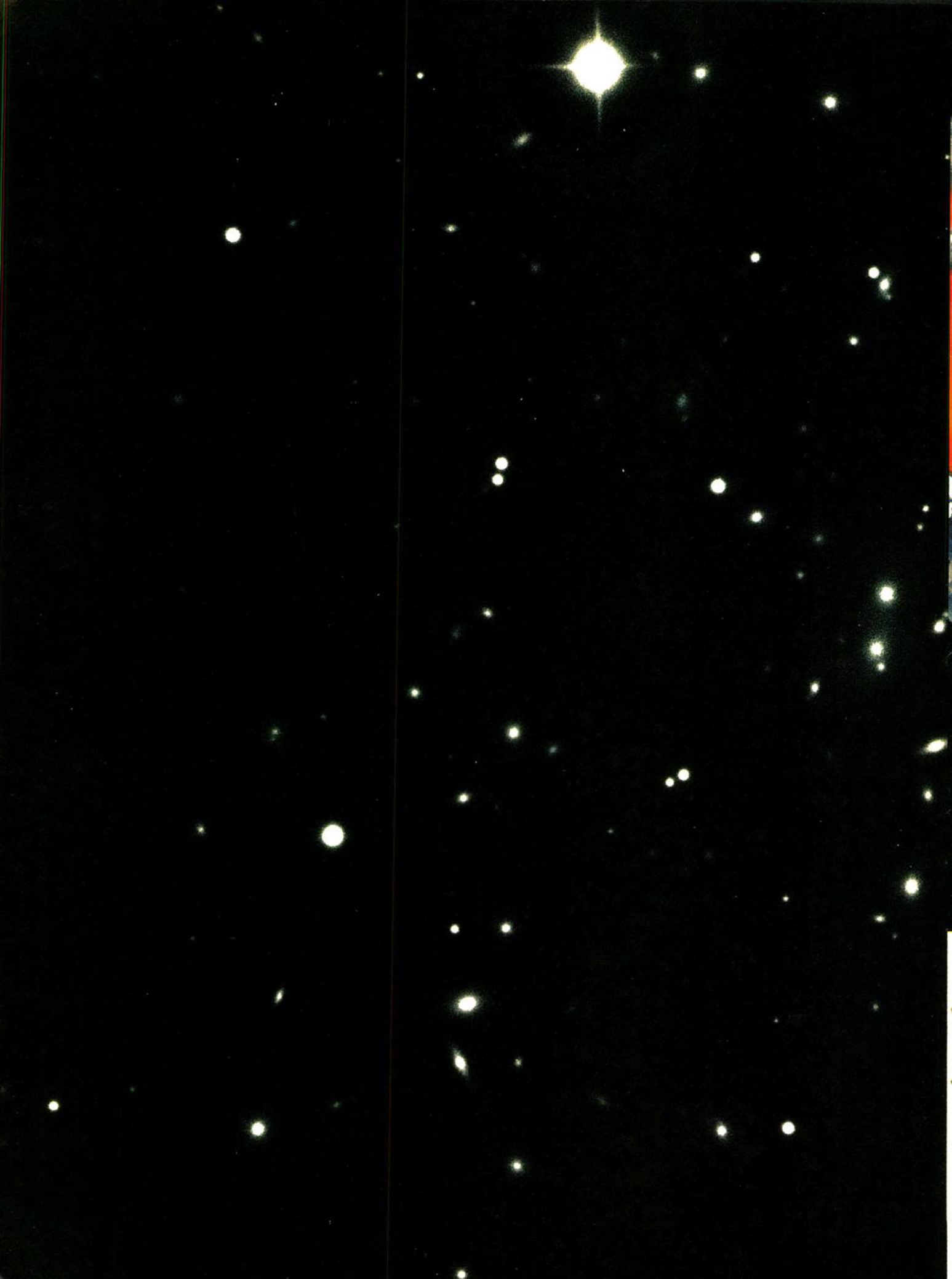
differently. There are no great apes in the New World, no evidence of ground-dwelling experiments of any kind . . . the rain-forest monkeys, effectively equipped with prehensile tails, still cling to their archaic pathways. . . . Here ended another experiment which did not lead to man, even though it originated within the same order from which he sprang. Another world has gone astray from the human direction."

If you are objecting that these failures are really failures of the environment to provide proper ecosystems, then you are correct. As in the quote from Stephen Jay Gould on page 10, natural selection results merely tracks the environment; the process *does not* guarantee intelligence as its final product.

Estimating N from the Expanded Drake Equation

If the multiplication of probabilities and the assignment of sometimes very uncertain values to them is justified in the original Drake equation, then surely we can factor f_i as the product of those evolutionary steps

Overleaf: A mirror to humankind, incomprehensibly distant clusters of galaxies may harbor dozens of sentient races — but the vast scales of time and space in our universe may swallow them without a trace. Cluster of galaxies in Corona Borealis photo courtesy Mount Wilson and Las Campanas Observatories.





we have discussed. Ornstein to some extent has already done this. We merely replace f_i in the original equation with:

$$f_i = p_P \cdot p_{PO} \cdot p_E \cdot p_S \cdot p_A \cdot p_{MC} \cdot p_{LP} \cdot p_{VL} \cdot p_{AN} \cdot p_T \cdot p_{BP} \cdot p_{CI}$$

where f_i is the product of twelve biological probabilities in the chronological order of their occurrence. Including these factors corrects, to some extent, the biological-to-astronomical imbalance of the original Drake equation.

Can we estimate any of our dozen probabilities? The first five Precambrian factors seem to have been "laborious," but given adequate time are probably not infinitesimal. Multicellularity seems to have probability close to unity. If the Earth had collected a somewhat larger "volatile water-bearing veneer" in the last stages of its formation, the continental coast line would have been reduced, affecting both p_{LP} and p_{VL} , the probabilities relating to the land invasion by plants and animals. A random innovation like the angiosperms, or its alien equivalent, seems impossible to predict.

Based on the Australia-South America argument, perhaps we can estimate that p_{BP} is equal to or less than 0.3. The descent of the great apes to the ground would suggest that p_{BP} is equal to or less than 0.2.

Certainly the final probability, that of the evolution of cognitive intelligence, must be small. But suppose that we gloss over the manifest uncertainties in these probabilities and assign to each the value one-third. Most would agree that this is a very generous estimate. Then:

$$f_i = (1/3)^{11} = 3^{-11} = 6 \times 10^{-6}$$

This means, using values often assigned the astronomical factors, that:

$$N = 6 \times 10^{-7} \cdot L$$

If L — the communicative lifetime of a civilization — is roughly a million years, then we are the only technological civilization in two Milky Way spiral galaxies. If L is 100 years, then we are unique among 20,000 such galaxies.

Enthusiasts may find means to get around this conclusion. But they will have to deal with biological, not astronomical, factors, for we have already pushed the astronomical factors to their plausible upper limits. A possible way out is to imagine that technological civilizations, in a desire to signal their existence, will construct star-powered beacons that outlast their own tenure in the Galaxy, pushing L up to a billion years. Several hundred such beacons might then exist within our Galaxy.

Alternative schemes may occur to others.

Of course, our "pessimistic" conclusion is still theoretical and admittedly quite speculative. It ignores, for example, alternate biologies. And like all theoretical predictions it is subject to experimental and observational verification. One way or another, the search for extraterrestrial life must be made, but it may well try the patience of the most dedicated observers. In the end, the search may seem to have failed by yielding no positive result.

But such an outcome could carry far deeper implications for us than would a Galaxy full of chattering alien civilizations. It would imply, as James Trefil has written, that: "We are not the snail darters of the Galaxy

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— one more life form whose ultimate fate is of little moment in the grand scheme of things. If we succeed in destroying ourselves, it will be a tragedy not only for the human race but for the entire Galaxy, which will have lost the fruit of a 15-billion year experiment in the formation of sentient life."

If our arguments are correct, then the misfortune would be several thousandfold greater. One of my students, Sally Green, summarized our conclusion best: "I walk away from here with a delighted reverence for the amazing, chancy development of carbon-based life on this planet . . . we are caretakers of the most fragile bloom in the universe . . ."

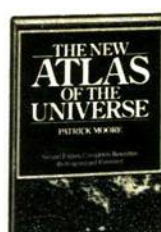
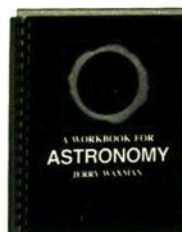
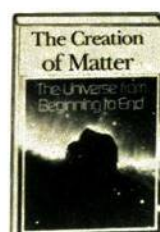
Edward C. Olson is an astronomer at the University of Illinois who normally does photometry and spectroscopy of interacting binary stars. His interest in life and exobiology grew out of reading Sagan and Shklovskii's Intelligent Life in the Universe, and this article grew from a one-semester course on life in the universe.

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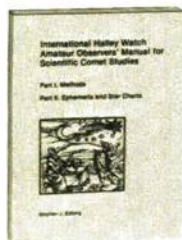
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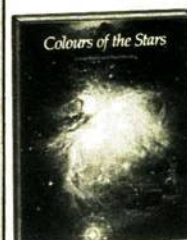
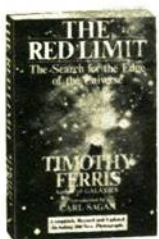
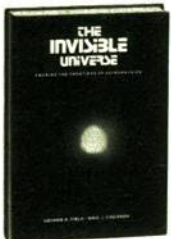
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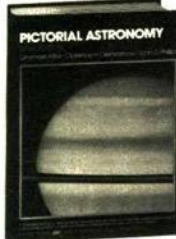
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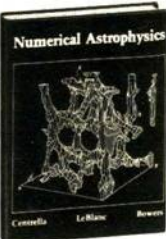
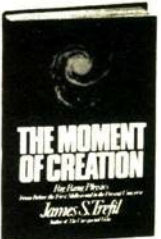
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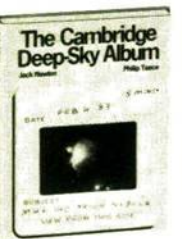
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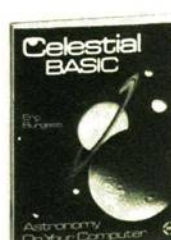
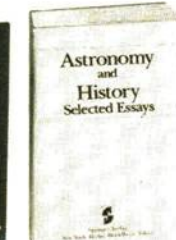
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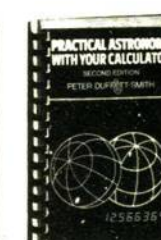
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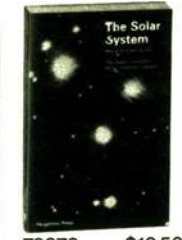
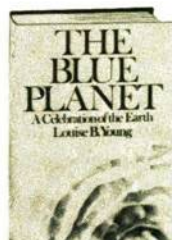
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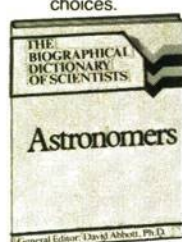
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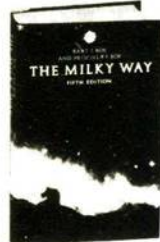
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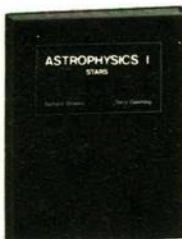
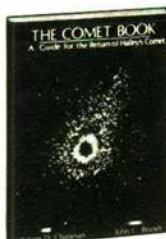
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ASTRONOMY Forum

Fireflies

As the horizon covers the Sun and daylight fades into twilight and finally night, darkness seems to take over the world. Yet this ending of daylight is also a beginning. For the stars, dusk is dawn. As our Sun withdraws from the sky, more distant suns appear and shine their fainter daylights onto Earth. With the stars emerge a few galaxies, the combined daylight of billions of suns, shriveled by distance into faint specks. As lights emerge in the sky, they are joined by those on the ground — street lights, house lights, car lights, and advertising signs — and cities turn into galaxies, complete with arms and wandering stars.

On this evening I was walking away from the city, away from the glare of the human-made galaxy, so that I might enjoy the stars and a real galaxy. I headed down a country road, turned into some woods, crossed a stream, and emerged in a meadow of tall prairie grass — a meadow circled by trees and nearly enclosed by a broad stream. I stood there for a while and looked at the far woods silhouetted against the sky. The sky was empty of clouds and full of twinkling stars. The same air that made ripples in the starlight now moved over the land and made ripples in the grass.

I knew this meadow well enough that I could find my way through it in the dark, and I began moving along the edge of the woods. As I approached one bank of trees, stars seemed to appear in their branches. But soon I saw that these lights were flashing on and off and some were moving about. It was June and the fireflies were mating. The trees contained hundreds of pale green lights, lights that glowed for several seconds, fading off and then glowing on again. Other lights were spread through the grass; as they blinked on and off, they vaguely illuminated the

stalks and leaves and flowers on which they sat. Now and then a light detached from a tree and drifted toward the ground, and others rose from the grass and climbed toward the trees. As they moved through the air, they left faint traces of their paths and then disappeared, showing themselves again a short distance away. Often the flying lights curved this way and that, spelling out a "J" or an "S" that may have had more meaning to other fireflies than to me.

I stood and watched the crowd of lights shifting about, flickering on and off, while above, the unmoving stars flickered more steadily. I enjoyed the way the lights in the trees blended with the lights in the sky. In my imagination, I saw the fireflies as stars and myself amid a strange constellation, or in a planetarium where stellar motions are speeded up. Then I realized that the fireflies truly were stars; or rather, they were all pieces of one star — the Sun.

The light emitted by the fireflies had once been emitted by the Sun. This energy had been squeezed from the heart of the Sun, which had flowed in dense, turbulent currents of matter and energy. It gradually worked its way outward and finally reached the surface, flying into space. It traveled across millions of miles. Then it ran into a planet of blue and green and white. It streaked through the atmosphere, passing the white, heading toward the green. It fell on leaves and was snared in tiny chemical traps. The energy was moved about and made to hold molecules together or run various processes. These little pieces of the Sun flowed through cells full of activities quite unlike those they had known inside the Sun. Then one day some fireflies came along and nibbled on these plants, swallowing mouthfuls

of sunlight. The sunlight flowed through their chambers and passageways. As it flowed into one particular chamber, it was touched by some molecules and set loose to fly through the translucent skin of the fireflies. After a long imprisonment, the sunlight was flying free again.

The lights before me were tiny pieces of vanished days, days the fireflies had revived for one last flicker. As the lights flashed, I saw little pieces of last Thursday or last Tuesday or last Saturday, of days or weeks or months ago. Each flash was a mixture of many days, though some may have been only one. Last Monday flashed on, then Wednesday and Sunday, then a mixture of Sunday and Monday and Tuesday and Thursday, and finally a mixture of all the days of last week. As the yesterdays flashed and flashed I thought of how the light of those days had warmed my skin, guided my journeys, and carried the shapes of letters from books to my eyes. When those days had come to dusk I had thought they were over, but here they were, shining on me once again.

Yet something about this light was very different now. The light that shined on me last week had been produced by brute force, by massive amounts of matter forced by gravity to pound against itself and rip apart. The light shining on me now was generated by something refined and skilled; in the fireflies, matter had learned the secrets of its own workings and codified that knowledge into genes and into the molecular keys that could gently unlock light from matter. In the Sun, the light had been helplessly swept along on waves of matter and energy and spewed into space like smoke from an engine, but in the fireflies, light had become the driving force for the delicate processes of life. In the Sun the light had contributed to the chaos of the Sun, but in the fireflies it helped build a highly intricate order. In the Sun the

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light had constantly collided with other particles and ricocheted away, but in the fireflies light tied together long and complicated molecules. From the Sun the light had been fired aimlessly into space, meant for no one, but for the fireflies this light was a signal full of information for other fireflies. Most of the light that poured from the Sun disappeared futilely into space, but the light of the fireflies would lead to the merging of genes and the creation of new life.

As I watched the fireflies flashing and lifting off and swirling against the light of the stars, I saw that the wild fierce energies of the universe — the energies pouring massively from trillions of stars — had been crafted into the gentle energies of life. I saw that the ceaseless streaming of matter — the streaming of electrons in atoms, the swarming of particles inside stars, the swirling of moons around planets and planets around stars and stars around one another, the streaming of stars around the center of a galaxy, and the streaming of galaxies away from the Big Bang — this wild fierce dance of matter had choreographed itself into the gentle dance of molecules through cells, which multiplies itself into all the forms and activities of life. As I looked at the trees before me and the grass around me, I saw them as a skillful dancing of particles, and I saw this dancing of particles multiplied into the mating dance of fireflies through the air. The fireflies flickered against the stars, and I saw that the blindly rushing matter and energy of the universe had taken on wisdom and purpose. In the fireflies, starlight had become the light of consciousness. And in the midst of the stars and trees and grass and fireflies I saw myself — the blind furious cosmic dance turned into a mind that could understand it all.

For a while longer I saw the fireflies as a vision of a universe that had become alive, but then this vision lost intensity and faded away. I watched the fireflies and saw simply fireflies. They glowed in the trees. They curved and hovered in the air. They flickered on and off. And then a new vision suggested itself and began to grow.

I was looking at the contrast between the blinking fireflies and the steady light of the stars when I realized that the stars were not really steady. In a longer perspective, the stars too blinked on and off. The stars would blink on and off only once, but would stay on for millions or billions of years. With a little imagination, I saw the fireflies as stars — forming from gas and igniting and drifting through space for awhile, and then dying out. I watched a light blink on, and around this light I imagined planets forming and evolving in various ways. I

watched the star wander among other wandering stars. Finally I saw the star exhaust its fuel and turn dark to wander invisibly through darkness. One after another, stars blinked on. I witnessed the prodigality of the universe. Yet as the stars disappeared just as steadily, I also saw how fleeting things could be in this universe.

Then I saw the fireflies not as stars, but as whole galaxies. Each light blinking on was a galaxy forming out of the gases spewed from the Big Bang. Each light blinking on was billions of stars turning on, stars that swirled about the galactic nucleus, stars that continued turning on and off by the millions but that in their combined masses maintained a steady glow. I watched galaxies flying through space. I saw them swerve and cluster. And then I saw the galaxies turning off.

Finally I saw a firefly as the entire universe.

A firefly blinked on, and I was seeing the Big Bang — the blast of energy with which the universe began. The firefly glowed for a moment, and within this glow I saw billions of galaxies glowing. Then the glow faded away, for all the galaxies were dying. Finally there was only darkness — only darkened galaxies rolling through the darkness forever.

When seen from the perspective of eternity, this is what the universe seems like — a firefly's flash. The massive light of the Big Bang, the fierce outpourings of quasars and supernovas, the outpourings of all the stars of billions of galaxies — all are contained within this flash of light. This flash also contains the entire history of life and civilizations: the long groping evolution of chemicals into cells, of cells into larger forms, and of these forms into intelligence; the building of cities and nations; the creation of languages and cultures; the discovery of the workings of the

universe; the exploration of solar systems and the slow spreading of civilizations from star to star — all occurred inside this flash of light. Perhaps billions of civilizations will cover their planets with machines that pour out energy, yet all of this energy will be only a tiny part of this flash. Or perhaps billions of firefly planets will flash in the night, yet this too will be but a tiny part of a much larger firefly's flash.

There is something in humans that feels threatened by such a vision. When we realize that for most of its history, the universe will be dead and dark — that we and everything we know will be swallowed in eternal night — we feel insignificant. Yet something about this feeling is wrong. It is significant that the universe contains any light at all, for it could have contained nothing more than dark stone and gas. It is even more significant that the universe created light for many tens of billions of years. It is significant that some of that light turned into life, that it flowed into bodies and inspired molecules to dance and weave themselves into intricate patterns, that it lifted dust and water out of the ground and turned it into forests and meadows, that it became the soft green glow of fireflies, that it became the pulses for uncountable heart beats, that it carried images from the eyes to the brain, that it powered the walking of animals, the swimming of fish, and the soaring of birds through the skies. It is significant that some of that light flowed into brains and transformed itself into a brighter kind of light, a light that enables the universe to see itself. Instead of a universe forever dark and unknowing, the universe has shined this light upon itself to discover what it is and what it will be doing for eternity.

Don Lago
Columbia, MO

The Curse of the Full Moon

Maybe it's not the horror story you think it is, but there's only one way to find out . . .

Frustration! Here you are with time on your hands for the next three evenings, but as you stand in the backyard looking at a beautiful star-powdered sky, it's already getting light in the east. You're tempted to get the scope out, but the Moon will be up in less time than it takes to wrestle the tube out of the garage.

To add insult to injury, the weather is nearly perfect. No wind, warm for this time of year, and the sky transparency is better than it's been for two weeks. As you stand watching the

horizon brighten, you'd hardly be blamed for imagining that a curse has been put on amateur astronomers. It seems that during the dark nights of every month, there are either clouds, or evening business meetings, or school functions you'll be dragged to by the kids, or the folks down the street who leave town for a two-week vacation and "forget" to turn off the mercury vapor light on their garage. Oh well, there's always television!

This is the attitude that takes a lot of the fun out of amateur observing. Sure, a Full Moon is a pain in the eye for dedicated deep-sky observers, but it isn't the end of the universe. There are

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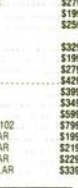
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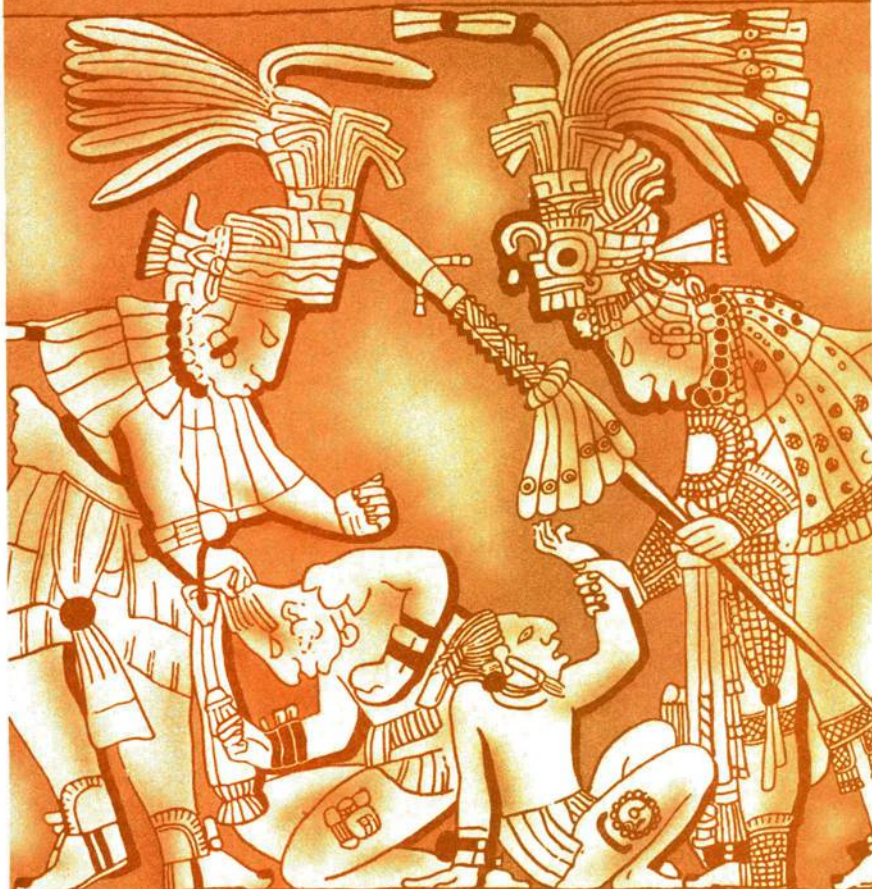
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a lot of other interesting and useful things that can be done while the Moon is hanging overhead — and I don't mean things like watching television or kicking back in the recliner with the latest copy of *ASTRONOMY*. Nor am I referring to that unfinished short-focus refractor knocking around in your garage. I'm talking about observing — that's right — observing while a Full Moon rides the sky, blotting out all of your favorite deep-sky objects.

For instance, when was the last time you *really* looked at the planets? No, I don't mean the 30-second shot you always give Jupiter before getting down to the serious business of digging out those 13th magnitude galaxies. Have you forgotten the thrill of seeing one of Jupiter's moons passing across the face of the planet? The air is calm; the seeing appears to be excellent. Maybe tonight would be a good time to try out that 6mm eyepiece you bought three years ago and have never used.

There are other planets worth looking at, too. Have you forgotten

that you saved a finder chart for Neptune? Maybe you should just slide into the garage and get the tube for the 8-inch. While you're at it, dig around for that list of double stars you copied out of a magazine last year. Most of them are bright enough to see well, even in a moonlit sky, and you've been promising yourself that one of these nights . . .

The point I'm trying to make here is that a Moon-brightened sky is no reason to suffer through sitcoms or roam the house gnashing your teeth. If you don't feel like setting up the telescope, flop down in a lawn chair with your binoculars and start picking out the brighter open clusters. You'll be amazed at how many you can see.

It's axiomatic that when the Moon is up, the weather is good, so you might as well make the most of it. Make a list of the things you might do on those otherwise perfect evenings. For example, didn't you decide that one of these evenings you were going to determine the exact field of view for each of your eyepieces? It would be a big help to your galaxy hunting (in

fact, it will help all of your astronomical pursuits), but somehow the project always got put off.

By using the star drift method, you can precisely define the actual field of an eyepiece. But before you start, how about collimation? You've been suffering with that finder for several weeks now. You're so used to putting everything in the upper left of the finder to center it in the main scope's eyepiece, you've forgotten that a few minutes work would get everything aligned and tidy. While you're at it, how about checking the main optics? To do this, pick out a fairly bright star and examine it on both sides of true focus so that you get a nice round image with the diagonal and spider evenly centered in the bright field. It isn't centered? How interesting. Maybe that happened last week when you whacked the tube into the doorsill carrying it back into the garage at 2 a.m.

Oh well, since deep-sky work is shot, why not take a few minutes to touch things up? That Allen wrench is here somewhere. That's better. Now check it at different positions — the mirror may be a bit too loose in the cell. Looks okay now. Swing it over to the Double Cluster in Perseus. Pretty, isn't it?

Wasn't it nice when you lined the crosshairs of the finder up on the cluster, looked in the main eyepiece, and there it was? Star images appear nice and sharp too. A quick switch of eyepieces from that wide-field Erfle to one of those higher-power jobs you almost never use makes the sky background darker. Now you're really seeing into the center of the cluster. Some of the fainter stars don't show too well, but it's a lot better than you thought it would be.

Now let's try the Moon. No, I'm not kidding. Use a couple of filters to cut the glare and you'll be surprised at what you can see. Try piggybacking a neutral density filter on a deep red one. Rays really stand out, don't they? You can track them almost all the way across the surface in some places. See how sharply defined some of the craters are while others just fade away? Note how the red filter emphasizes the contrast between different types of terrain. It's like looking at a completely different Moon.

Arrgh! What's that light? Car turning into the driveway — but it can't be the family back from the movies already! I'll be, it's nearly midnight. Look, I gotta go. How about tomorrow night? I'll bring some AAVSO charts along. Betcha we can work out some of those variables down to mag 10 or so. Mag 12? Probably not, but there's only one way to find out . . .

Richard Bean
Hesperia, CA

ASTRONOMY

Finding True Field of View Using the Eyepiece Drift Method

One thing all amateur astronomers should know is the actual field of view for each eyepiece they own — including the viewfinder of their telescope.

Knowing the field size is helpful for several reasons. First, when starhopping from one object to another in the night sky, accurately knowing how much sky you are seeing in the finder or main eyepiece tells you how much you must move the telescope from a known object to center the object you are hunting for in the eyepiece.

For example, the 8x50 finder on my 8-inch f/6 Newtonian has a 4.18° field of view. Knowing this, I can pick out an easily-recognized star on my charts near the object I want to locate and then accurately judge the offset required to put the object in my field of view. If it's less than 4°, I know it will be in the finder's field with the starting star still in view. If it's more than 4°, I can estimate how many fields of view I must move the telescope to locate my target. Knowing the actual field size of each eyepiece also makes it easier to accurately measure for comets and planetary features.

In addition to finding the actual field of my finder and eyepieces, I made a simple chart overlay from a piece of thin, transparent plastic. On it are scribed circles showing the field of the finder and the field of my lowest power eyepiece. Placing this on the chart makes it easy to tell what should be in view, or how far I must move the telescope to center the object in the eyepiece.

To find the field of view using the "star drift" method, we take advantage of something that is usually a nuisance to amateurs — the Earth's rotation. Objects in the sky rotate a total of 360° every 24 hours. At or near 0° declination (the

celestial equator), they move at a rate of 1° in four minutes, with the apparent movement lessening slightly for each minute of time as you move north or south of the equator.

The simple way to drift-check your eyepieces is to use a fairly bright star somewhere between +10° and -10° of declination. Start with your lowest power eyepiece, or finderscope if your telescope has one. With the drive turned off, set the target star at one edge of the field so that it drifts through the exact center of the field. This is easy to do with a finder's crosshair eyepiece — just align the crosshairs so that the star drifts along one line. Let it drift through once or twice to make sure it's nicely centered in declination, then time one complete transit with your watch.

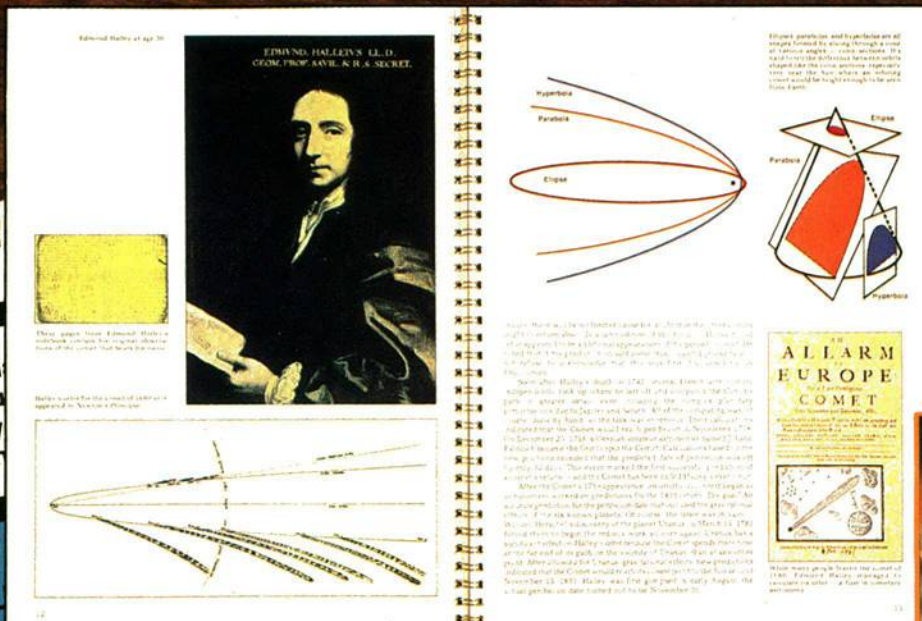
Each minute of drift will cover .25° in the finder's field of view. For every four minutes, the target star will move 1°. Totalling up the minutes and seconds of drift time will give you a fairly accurate determination of your finder's field of view.

This procedure can take a couple of hours to complete if you have several eyepieces, but it only has to be done once for each particular combination of eyepiece and telescope. Note that if you choose a target star above +10° or below -10°, the degree per minute of drift time becomes smaller. Most observing handbooks contain a formula for using this procedure with stars of higher declination, but there are plenty of bright stars between +10° and -10°, so you shouldn't need to look it up. An excellent set of target stars are those in the belt of Orion.

You can make some good crosschecks on field sizes by using the Moon and planets. The Moon is approximately half a degree wide, and *ASTRONOMY* publishes the angular size of all the planets each month in the Backyard Astronomer.

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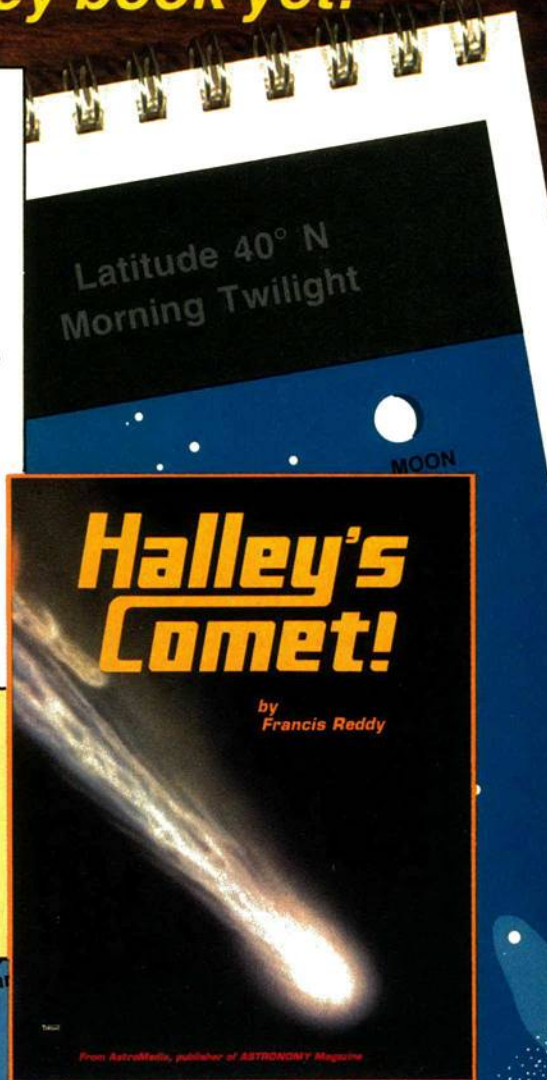
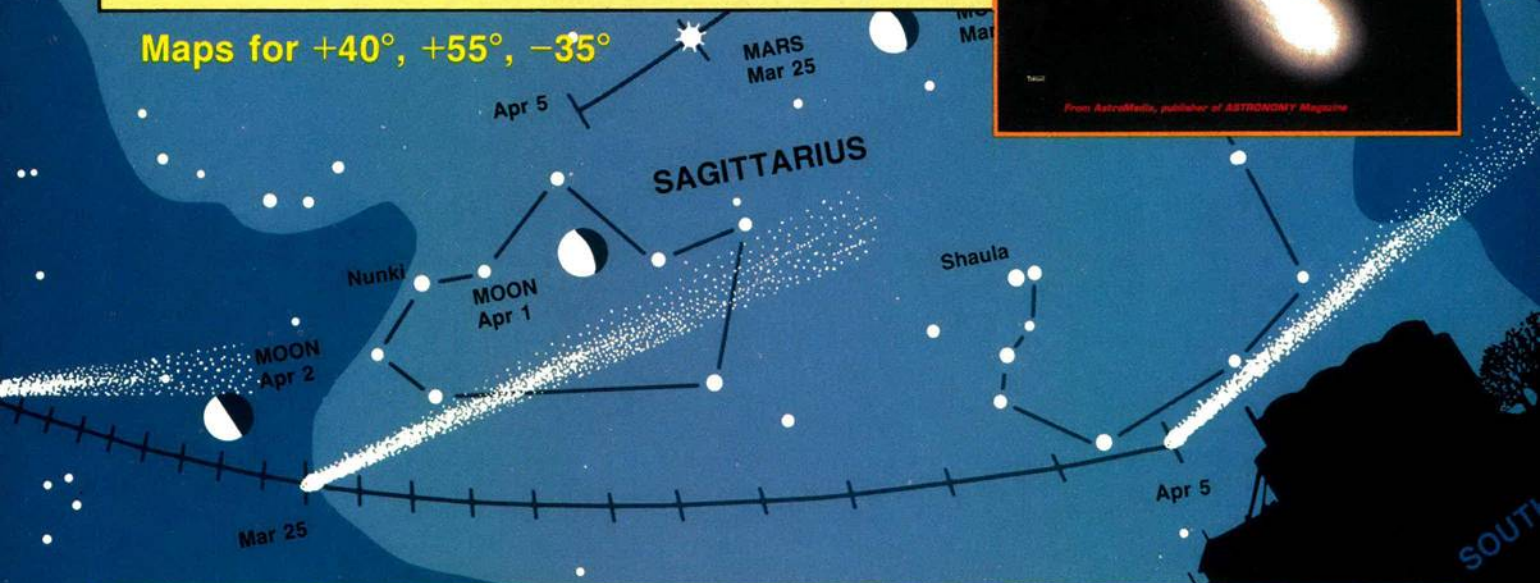
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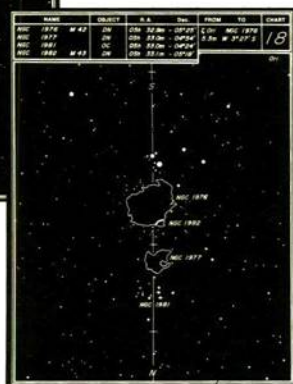
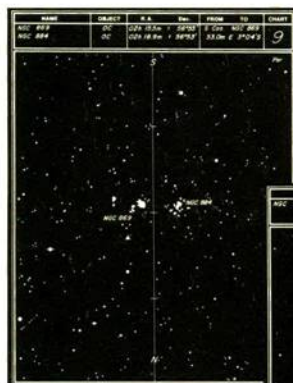
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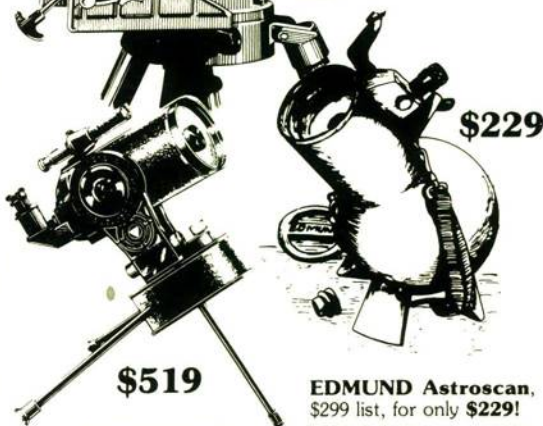
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In Focus

Tour Tips for Halley

Sir / The International Halley Watch has received numerous requests for tour information from individuals who are making travel plans to view Halley's Comet; some of this advice may assist your readers.

Firstly, satisfy yourself that the tour you select will provide the services and accommodations you desire, and that you are dealing with a reliable organization. Matters to consider when evaluating the various offerings should include the following:

1. What is your primary goal for a tour — to see the comet, to tour a place, or both — and how intensively will you pursue this goal on the trip?
2. Is there sufficient time scheduled for your primary activities?
3. What are the weather prospects for the area being visited, in particular, at the places where comet observations are planned? Remember that cloud-free skies do not necessarily mean high transparency.
4. Are the observing sites properly situated for minimal interference from air and light pollution? Can you make your desired observations from these sites?
5. Are the scheduled observing periods properly coordinated with the Moon's phases and with the best dates for observing the comet?
6. What instruments will be available for viewing the comet? Are provisions made for carrying your own observing equipment? If so, what weight or customs restrictions are there? Is an appropriate power supply available?
7. Are there any other events (astronomical or otherwise) that you want to coordinate with your travel plans?
8. Do personal health restrictions limit the places you can visit?
9. Is the local political situation of the country being visited a concern?
10. Besides considering overall cost, look at the modes of transportation offered, the quality of accommodations, the number of meals included, group size,

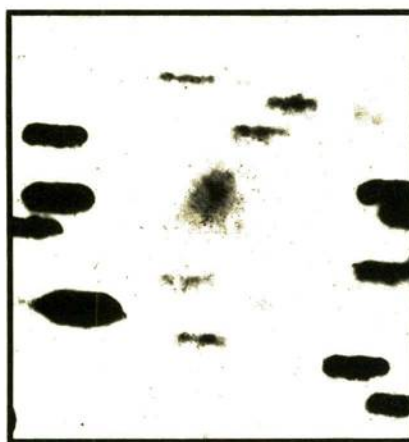
leadership, and the reputation of the organizers.

Stephen J. Edberg
International Halley Watch
Pasadena, CA

Amateurs Photograph Halley

Sir / We are glad to inform you that Halley's Comet was detected on February 18 and 19, 1985 by the undersigned. As far as we know, it is the first French amateur detection of Halley on this return — and one of the first in the world.

The telescope was a 60-centimeter reflector on loan to amateurs by the Pic du Midi Observatory. The focal length was 2.1 meters: our exposures



ran one hour (guiding on the comet) on Kodak's 2415, hypersensitized by forming gas.

The comet appears as a point (magnitude approximately 19) on one plate taken February 18th and on two plates taken the 19th. Between the two plates, the motion of the point is exactly that of Halley, showing it really is the comet.

We haven't completely examined films taken February 20th, 21st, and

22nd. But when we're finished (in about two weeks), we'll send you all the photographs.

Patrick Martinez
Eric Laffont
Toulouse, France

— *Luckily, the pictures arrived before we went to press — see adjoining.*

Ooops!

Sir / How interesting to read in the article "Comets: Key to Our Solar System" (March 1985) that Edmond Halley and Isaac Newton viewed the comet of 1607 — especially since they weren't born until 49 and 35 years later, respectively.

Otherwise, a fine article.

John N. Swanson
Thousand Oaks, CA

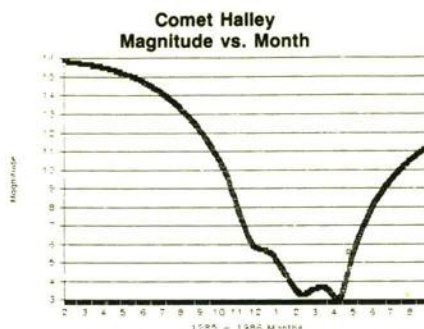
— *Right you are. Newton and Halley saw this comet in 1682, not 1607.*

Charting Halley

Sir / Thank you for the computer program "HALLEY.BAS" in your February 1985 issue. After an evening of coding it into my Compaq computer and debugging it for the MS-DOS version of Basic, I modified the program to automatically provide input using the FOR/NEXT commands. The result is a printout of the comet's coordinates, magnitude, and distance in AUs from the Sun for each day between now and August 30, 1986.

I plotted the output from the program and obtained an interesting graph (attached) of magnitude versus time. You will notice that the calculated magnitude of Halley takes a "dip" in December 1985, February 1986, and again in April 1986. What is the explanation for this in terms of the comet's motion?

Again, thank you for a fine magazine and the useful articles.



Robert C. Carlson
Newtown, CT

— The dip is actually the result of two peaks — one in February when the comet reaches perihelion, and the other in April when Halley passes close to the Earth. On both occasions, the comet appears bright, but for different reasons. Note another peak in December at the first close approach.

Waiting for Halley's

Sir / After reading Behind the Scenes in the February issue, I got to thinking: Who's been waiting for Halley's longer than I?

I was born in 1910. My mother used to tell me what a sight the comet was that year. In the late 1930s I acquired a copy of *Amateur Telescope Making* by Albert Ingalls and, after trying to find someone who knew something about grinding a mirror, I bought myself a 6-inch mirror kit. Over the next three year (during which time I got married, went to work for the Post Office, and had a son), I finished polishing and figuring my mirror. Then it took another year to make a tube and mounting out of 2-inch pipe.

During all that time plus thirty years more, the comet was beyond the orbit of Neptune. At aphelion — in 1948 if I remember right — it had slowed to about a half mile per second. Then Halley started falling back.

My scope is still in the basement, waiting for me to take it to the Florida coast sometime next fall or winter. It has been so long since I have seen the Milky Way that I wonder if I will be able to see the comet with the trusty 1-inch eyepiece which John M. Pierce up at Stellafane made for me. He was my advisor back then.

By the way, I like your magazine. A lot of my old knowledge is creeping back to me, but I would like someone there to write an article on right ascension and declination and their use in finding objects in the sky. Probably some young amateurs would like to learn about this, just as older ones would like to be refreshed on the subject.

I put the Comet Ephemeris program

by Roger Browne in my Vic 20 and it works fine. I had to eliminate a lot of PRINTS and LETs, but that's always the case in programming.

Oh yes, I remember what Mark Twain said. But my doctor says I'm normal. So we're all waiting for Halley's! Right?

I remain your avid reader.

Arthur J. Hitchcock
Chattanooga, TN

— We're planning to begin a new series on basic astronomy this summer. It will include articles on R.A. and Dec. as well as other subjects we hope you'll find refreshing. And yes, you're right. We're all waiting for Halley's!

STAR.DOC Available

Sir / In reference to the item "Yale Catalog of Bright Stars" (August 1984, page 41), I acquired the data base from Public Domain Software and have written some

programs to access it. Although they are copyrighted (each contains the "Copyrighted Software Notice"), I am willing to make them available for non-commercial use.

The programs are written using dBASE II, ver.2.4 and a CP/M-86 operating system. While originally created for an NEC APC (8" double-sided, double-density disks), the source code could be easily modified for 5¼" disks. The programs would be provided on an 8" single-sided, single-density disk (IBM 3740 format). Individuals who desire a copy should send me an 8" single-sided, single-density disk and include a self-addressed return envelope affixed with postage in the proper amount. The turn-around time is one week at the most.

Please note that the programs I supply DO NOT include the data base, which would need to be acquired separately.

H.O. Teeple
5015 Spalding Dr. NE
Atlanta, GA 30360

Behind the Scenes

Are We Alone?

This month's feature article is quite unusual for *ASTRONOMY*, for in it we attempt to define the number of civilizations in our Galaxy. This in itself may not seem so unusual, but astronomer Edward C. Olson explores the problem from a *biological* point of view. The article requires more than passing familiarity with current thinking in modern biology, although the major ideas are clear even if you don't understand the jargon and terminology perfectly.

Most people, I suspect, would like to believe the Galaxy contains many intelligent races that prove as friendly and good natured as they are intelligent. Quite often science fiction writers explore the opposite theme, evoking hostile aliens in their tales. Considering that we humans hardly get along well within our own species, and have been pretty tough on some of the other species on this planet, this seems worth serious consideration.

Science fiction has also explored the "galaxy full of planets inhabited only by dumb animals" hypothesis. It makes for interesting plots and plays with the very question we consider in the feature: What does it take to get from the origin of life to the rise of intelligent and communicative beings? How unlikely are we? Since we're the subject of our own question, it's a

very difficult one to answer.

In the end, though, I'm not too concerned that we're alone. Even if we put low probabilities into Olson's Equation — and therefore force the number of intelligent communicators in our Galaxy way down — the universe is still large enough to harbor countless intelligent species. We just don't get to talk to each other because we're too far apart.

Closer to home, the giant planets are coming 'round for another season of observation. It's time to wheel the ol' telescope out into the back yard to ponder the rings of Saturn and, after midnight, the cloud belts of Jupiter. Don't forget to look for Uranus and Neptune if you haven't seen them yet. We ran finder maps in the January issue.

And don't forget the sky *without* a telescope. If you "get away from it all" this summer, make sure you really do. Find a quiet spot where you can spend a few hours watching the spring constellations set, revel in the summer Milky Way, and renew your acquaintance with the late-rising constellations of fall. It'll probably do you good.

Sincerely,

Richard Berry
Richard Berry
Editor-in-Chief

Deep-Sky Duos

by
Jack Marling

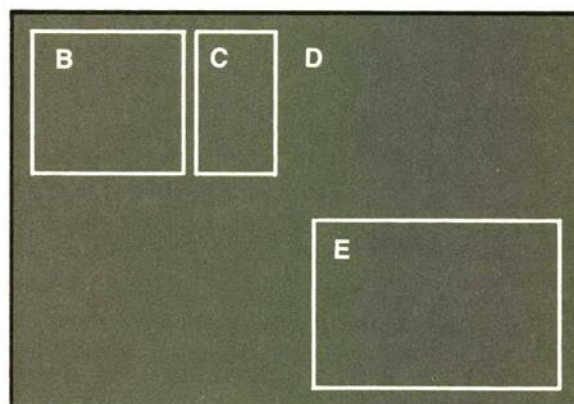
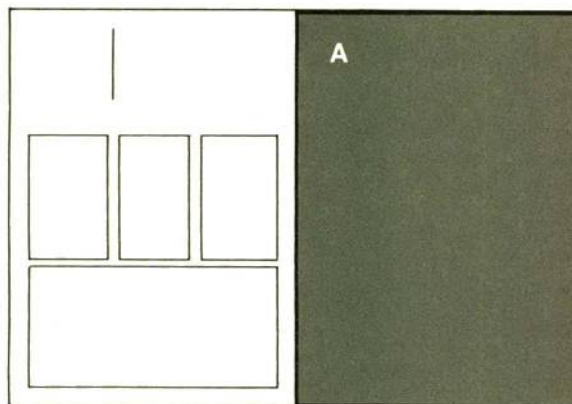
Do you remember the thrill of looking at a galaxy or nebula for the first time . . . or the excitement of sweeping across one you weren't expecting — a galaxy you didn't even know existed?

As I hopped from object to object during a recent night of observing, I was especially impressed by the spiral galaxy NGC-2903 in Leo. Through our astronomy club's 17½-inch reflector, I was thrilled to see its distinct spiral structure.

I left the eyepiece for a couple of minutes to make some notes. The clock drive wasn't working and when I returned, I thought NGC-2903 had faded. But I looked again and realized that the little fuzzy patch I saw was *another* galaxy — one not on any of my star charts! It seemed fairly bright — about 12th magnitude — but when I looked up NGC-2903 in *Burnham's Celestial Handbook*, I found nothing listed nearby. Finally, using

Gerard de Vaucouleurs' *Second Reference Catalogue of Bright Galaxies*, I discovered the little galaxy was NGC-2916 — mystery solved. But the experience was exhilarating.

Unknown to many deep-sky observers are a number of small, faint objects lying near some of the brightest, most often observed nebulae and galaxies. A few are involved with brighter objects (witness M-51's physically-connected interloper),



Key to Photographs:

The photographs in this article were carefully selected to show deep-sky objects lying in close proximity on the sky, but at radically different distances. Photos were made by Jack Marling using hypersensitized Fujichrome 400 and a 17.5-inch f/4.5 reflector, except (C) for which Marling employed a 10-inch f/5 reflector and (F) which was shot with a 4-inch f/15 refractor. Distances in parsecs are given in parentheses.

A: Horsehead Nebula in region of Zeta Orionis; ruddy emission nebula IC 434 (500), bluish reflection nebula NGC-2023 (500), dark Horsehead Nebula (125).

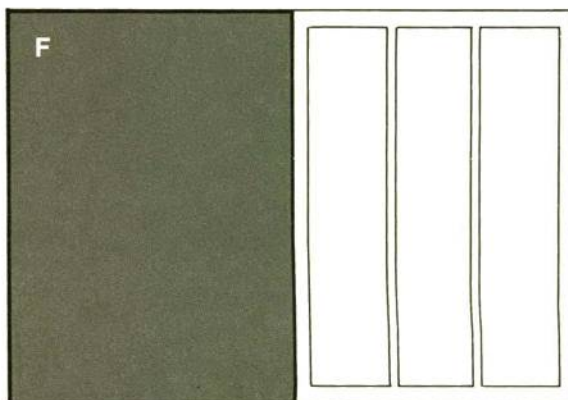
B: Star cluster M-46 (1660), planetary nebula NGC-2438 (1000).

C: Star cluster NGC-6939 (1250), galaxy NGC-6946 (4,500,000).

D: The Owl Nebula (400), galaxy M-108 (10,300,000).

E: The Hercules Cluster (7,200), galaxy NGC-6207 (14,200,000).

F: Star cluster M-21 (700), Lagoon Nebula (1600), Trifid Nebula (2,000), globular cluster NGC-6544 (4,500).











but most are simply line-of-sight neighbors. For an astrophotographer, they are extreme examples of "depth of field," since they lie at vastly different distances.

Brief Encounters

Bright comets occasionally pass well-known deep-sky objects as they float across the sky: in 1975, Comet Kobayashi-Berger-Milon passed alongside galaxy M-106 in Ursa Major; and in 1983, Comet IRAS-Araki-Alcock made a nice pair with the Beehive Cluster in Cancer for a short time.

One of the best "photo opportunities" to capture two objects in the same frame at radically different distances occurred December 5, 1980 when the eighth-magnitude Comet Stephan-Oterma passed directly in front of M-1, the Crab Nebula in Taurus. At that time, the comet was about 0.6 astronomical unit from Earth; the Crab Nebula is about 2,000 parsecs distant. (A parsec equals 3.26 light-years, or about 18 trillion miles.) Although both objects appeared as roughly equal patches of fuzzy light, one lay some 700 million times farther away.

So astrophotographers, get ready! In the coming months, Halley's Comet will slide right by such sights as the Pleiades Cluster in Taurus, the Crab Nebula, globular cluster M-75, and the strange galaxy NGC-5128 in Centaurus.

Milky Way Clusters and Nebulae

If you've observed any deep-sky objects at all, you've probably noticed one general characteristic about their distribution — they appear on the sky as groups of open clusters and nebulae found in the luminous Milky Way, or as globular clusters or clouds of galaxies away from the Milky Way's plane. Globular clusters are the Milky Way's loners: They are part of our Galaxy, but lie far away from its disk in the expansive halo. Because of this, it is unlikely you'll find globular clusters near other Milky Way objects like open clusters or nebulae.

But the Lagoon Nebula in Sagittarius — a rich region of nebulosity and stars — has a neighboring globular cluster just 50' to its south-southeast. The globular, NGC-6544, appears as a tiny circular smudge when viewed through telescopes or in photos. This ninth-magnitude cluster is severely dimmed by obscuring dust and gas; it would shine several magnitudes brighter were it not behind one of the Milky Way's arms. Here we have an unusual multi-depth view of the Galaxy, for the Trifid Nebula (M-20) lies just 1½° north of M-8. Furthermore, some 50' northeast of the Trifid is the scattered open cluster M-21, an easy target in binoculars. M-21 is the foreground object at a distance of some 700 parsecs; the Lagoon Nebula lies 1,600 parsecs away, the Trifid some 2,000, and the tiny globular NGC-6544 is 4,500 parsecs off.

In the winter sky, the constellation Puppis contains an unusual juxtaposition of four open star clusters — M-46, M-47,

NGC-2423, and NGC-2325. On a dark night, you can spot this area by training a finderscope or binoculars 10° east of Sirius. M-46, a bright cluster some 30' across, is composed of innumerable faint stars. Just 1½° to the west of M-46 lies M-47 — a much sparser, brilliant cluster of stars. The seventh-magnitude open cluster NGC-2423 lies 37' north of M-47 and contains about 60 faint stars. And as if three clusters weren't enough, tiny eighth-magnitude NGC-2425 lies between M-46 and M-47. With such a grouping of open clusters, you might think they're physically associated. No chance. M-47's members appear bright not because they're intrinsically luminous, but because they lie only 480 parsecs away. NGC-2423 is nearly twice again as distant, while M-46's faint stars are a whopping 1,660 parsecs away. The distance to NGC-2425 is not yet well-established.

Dedicated deep-sky observers know that M-46 has one very curious feature — a 12th magnitude ring-shaped planetary nebula resembling M-57 in Lyra. Contrary to deep-sky lore, the nebula NGC-2438 is *not* a member of the cluster; it lies about 1000 parsecs away from Earth, just over half the distance to M-46, and is a foreground object that appears "in" the cluster strictly by accident.

Diffuse nebulae are far more complex than planetaries. Both emission nebulae — reddish ionized gas excited by hot stars — and reflection nebulae — bluish dust grains reflecting starlight — are often found near each other. A grand example of this is the region of Zeta (ζ) Orionis, the easternmost star in Orion's Belt. Here lies a faint strip of emission nebulosity called IC 434, which backlights the famous Horsehead Nebula — a dark dust cloud. Nearby is the pretty reflection nebula NGC-2023, a circular bluish patch. The Horsehead is not a "hole" in the emission nebula; rather, it is a separate object suspended in front of the more distant band of nebulosity. Distances to such nebulae are very difficult to determine, but both IC 434 and NGC-2023 may lie at about the same distance as Zeta Ori — 500 parsecs. The Horsehead is conceivably 125 parsecs closer.

Moving Outward: Galaxies

In the plane of the Milky Way, open clusters and nebulae are common partners. It is quite unusual, however, to find a face-on spiral galaxy nestled alongside a bright open cluster. But bordering between the constellations Cygnus and Cepheus, in the richest part of the northern Milky Way, is just such a pair. NGC-6939 is a rich open cluster containing 80 stars in an area 8' in diameter; it shines with the light of a magnitude 7.8 star. The cluster's brightest star, a spectral type B8 supergiant, glows at magnitude 11.9. A low-power telescopic field trained on this cluster shows the fine galaxy NGC-6946 a mere 38' to the southeast. The combined light

from this galaxy is only a magnitude fainter than the cluster, but since the galaxy lies in back of the rich Milky Way, it is significantly dimmed by dust. Were NGC-6946 away from the Galaxy, it would be one of the sky's best spirals. As it happens, however, it must share attention with an open cluster; by comparison, NGC-6939 is a tiny insignificant object 3,600 times closer to home.

An impressive combination of a galaxy and a planetary nebula is found in the bowl of the Big Dipper. Although quite dim, the Owl Nebula (M-97) is a favorite deep-sky object for many observers, appearing as a roundish patch of grey nebulosity in small telescopes. Large scopes show not only the 14th magnitude central star, but the mysterious dark "eyes" which led Lord Rosse, a famous 19th century observer, to name it the Owl Nebula. Unknown to many observers is the edge-on Sc-type spiral galaxy M-108, which lies a mere 48' away. This galaxy has a small bright nucleus and is unusual for its patchy brightness distribution, appearing irregularly mottled with dark areas. The Owl Nebula lies some 400 parsecs away, while its neighbor galaxy is actually 10.3 megaparsecs off — M-108 is over 25,000 times more distant.

Groups of Galaxies

Galaxies exist in groups; they are clustered together by mutual gravitation. But some galaxies appear solitary as viewed on the sky since they are relatively nearby. A beautiful exception is the M-65 group in Leo, just a little less than 10 megaparsecs away. Here lie three bright spiral galaxies which appear clustered and are physically associated — even though their distances range from 7.8 to 9.7 megaparsecs. The spiral galaxy M-65 is a bright oval-shaped disk of nebulosity with a prominent dark lane spanning one side. It lies some 8.9 megaparsecs away. Forming the second corner of a slim triangle is M-66, a loose knotty galaxy with distorted spiral arms — it is only 7.8 megaparsecs off. Completing the trio is NGC-3628, an edge-on dusty galaxy with a broad dark lane spanning its entire length. This object is the most distant of the three, lying 9.7 megaparsecs away.

Even in the depths of the starry sky, you can find unusual combinations of deep-sky objects if you know where to look. Clusters born from nebulae, comets sweeping by galaxies, globulars hiding behind the Milky Way, planetaries neighboring distant spirals — all are waiting for you to seek them out.

Jack Marling is an accomplished astrophotographer and pioneer in gas hypersensitizing film. A former physicist at Lawrence Livermore Lab in Livermore, California, he now operates Lumicon, Inc.

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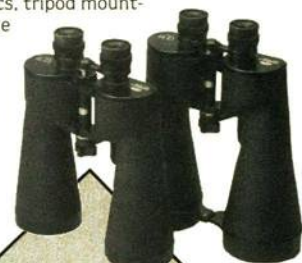
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July's Blue Moon

by
Fred Schaaf

The Wanderers

During July, Halley's Comet is still hidden in the Sun's glare, but while we await its predawn emergence and brightening, we have a fine and varied month of planets to enjoy. All except Mars are in plain view, and Venus and Jupiter both have remarkable conjunctions.

The only planet now rising in the predawn sky is -4 magnitude **Venus**, as it dims slightly but continues to gain altitude during the month. For the first of its conjunctions in Taurus, Venus cuts through a corner of the Hyades star cluster, moving to within 1° of Epsilon (ϵ) Tauri in the predawn sky on the 12th/13th. The planet can be seen about half a degree east of the star in the predawn sky on the 13th/14th. You won't be able to see the closest approach of Venus and this 3.6 magnitude star, but the mornings before and after should provide good scenes for the naked eye, binoculars and cameras (use a long telephoto lens).

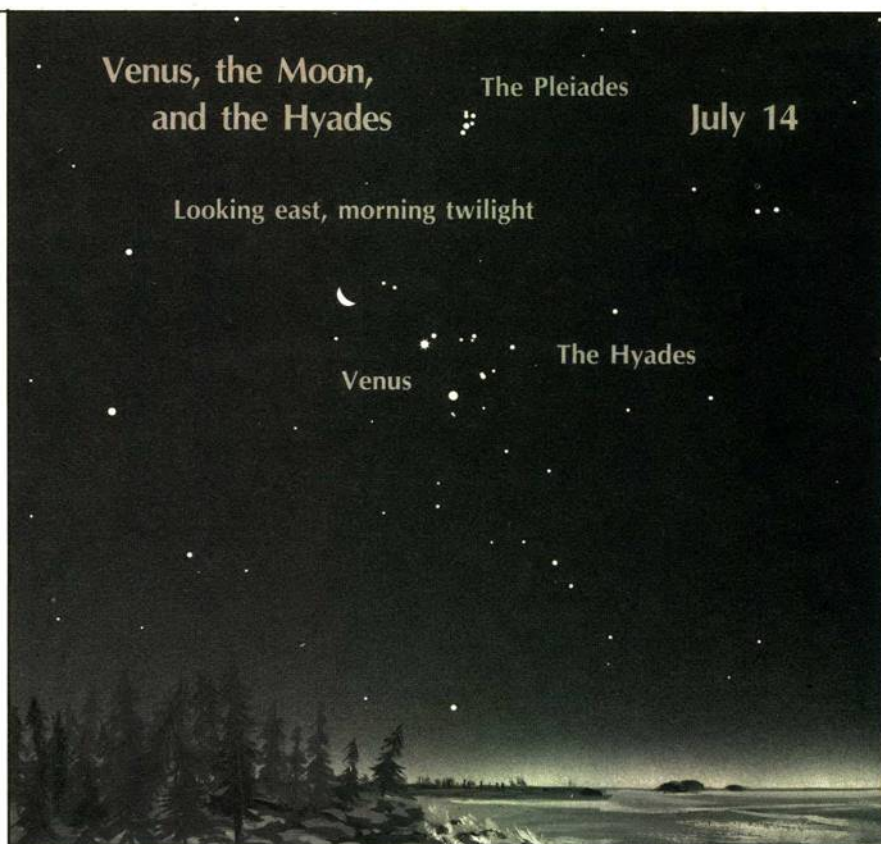
Just two days later, Venus lies 3° north of Aldebaran and there is an added ingredient to this scene: the Moon. Between the times of the two conjunctions, the Moon moves to within roughly 5° north of Venus on the morning of the 14th.

Venus' trip through Taurus continues long after the Moon has moved out of the picture, as it passes less than $15'$ north of Zeta (ζ) Tauri (and also close to the Crab Nebula) on the morning of July 28th.

If you get up to observe Venus rising in the east in the predawn sky, you can catch a last glimpse of **Jupiter** setting in the west, for Jupiter has been up in the sky since twilight the evening before.

During July, track Jupiter's retrograde motion past Theta (θ) Capricorni. On the 19th and 20th, a pair of binoculars will

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.



reveal the sixth-magnitude star SAO 164156 just south of -3 magnitude Jupiter. Don't confuse the star with one of the Galilean moons. Jupiter is currently in Capricornus, and about the same distance from the star Altair as Altair is from bright Vega.

While **Neptune** is in the midst of the Milky Way in Sagittarius and **Uranus** is just entering the edge of that luminous band in Ophiuchus, **Saturn** is sitting in Libra. On July 26 Saturn reaches its stationary point and then resumes direct motion. The planet fades somewhat during the month, becoming comparable to Altair in brightness.

In addition to Saturn and the other gas giants, the swift planet **Mercury** appears briefly in July's evening sky. It attains a greatest elongation of 26.6° on July 13th (eastern daylight time) — almost its largest of the year. The apparition is far from Mercury's best, however, for its elevation above the horizon is low due to the slope of the ecliptic with respect to the horizon. This slope is also partly responsible for making Mercury's time of highest altitude (for latitudes 40° north) about nine days earlier than greatest elongation. Look for Mercury in mid-twilight during the first week or so of July; it is in the Beehive star cluster on the 4th. It will be farthest from the Sun on the 21st — after which its low altitude will make it difficult to see even with binoculars.

No form of optical aid can help you find **Mars** this month. It remains on the far side of the Sun, reaching superior conjunction

on the 18th. The red planet is most distant from Earth on the 30th.

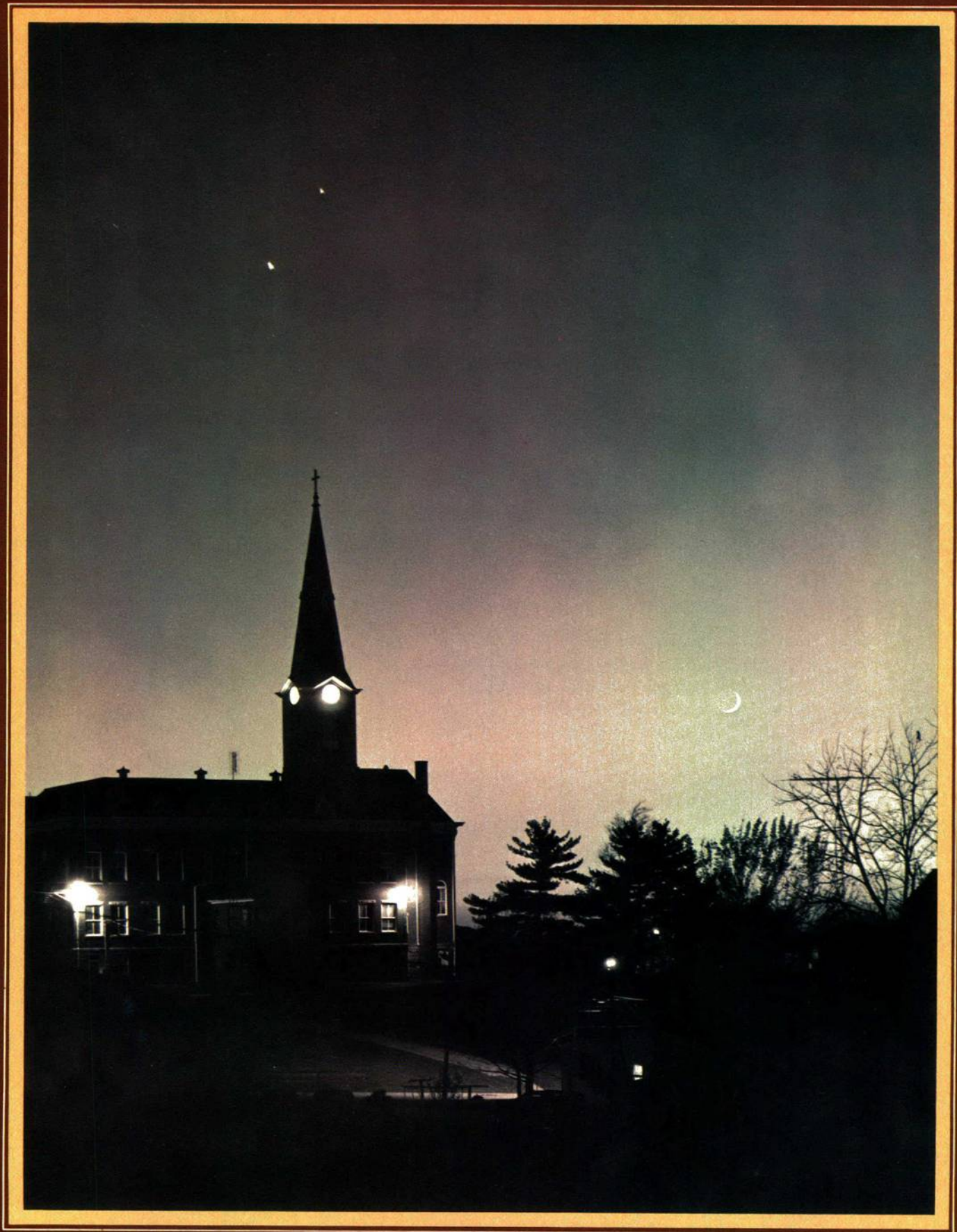
The **Delta Aquarid** and **Capricornid** meteor showers can be seen during most of July and early August. When the Delta Aquarids are at maximum on July 29th, however, we will be enjoying a Full Moon, so look for them after very late moonsets the week before Full Moon.

We should have said "**second Full Moon**" for this phase occurs on both July 2nd and July 31st in 1985. According to some people, the latter is called a "Blue Moon." More of this in Skylore.

The Starry Sky

Saturn's presence in **Libra** the Scales during 1985 may tempt you to take a closer look at this constellation. Sharp-eyed observers won't need optical aid to see the double star Alpha (α) Librae, **Zubenelgenubi**. If your vision is not acute, use binoculars to admire this pair. The same might be said for Beta (β) Librae, **Zubeneshemali**. Beta was reported to be brighter than first-magnitude Antares in ancient times, and though this seems doubtful, there is still cause to wonder if the star could occasionally be so variable. Alpha and Beta form a large diamond-

This November 1984 conjunction of Venus and Jupiter over the tower of St. Ferdinand Church was taken 1 hour and 38 minutes after conjunction by Marvin Klueh (50mm lens; 2-second exposure at $f/2$; Kodak Technical Pan 2415 film).



July's Night Sky



Full Moon
July 2
8:08 a.m. EDT

Last Quarter
July 9
8:49 p.m. EDT

New Moon
July 17
7:56 p.m. EDT

First Quarter
July 24
7:39 p.m. EDT

Full Moon
July 31
5:41 p.m. EDT

- 2nd** Full Moon occurs at 8:08 a.m. EDT.
- 4th** The Moon passes 5° south of Jupiter in the evening sky.
- 5th** Earth is at its farthest from the Sun: 94,760,000 miles.
- 8th** The Capricornid meteor shower begins; watch for them during most of July and early August.
- 9th** Last Quarter Moon is at 8:49 p.m. EDT.
- 11th** The Moon is farthest from Earth at 3:41 a.m. EDT: 251,194 miles.
- 13th** Venus approaches within 1° of Epsilon Tauri in the predawn sky on the 12th/13th. Mercury is at greatest eastern elongation — 27° in the evening sky.
- 14h** Venus, the Moon, and Aldebaran make a pretty sight in the early morning sky (see diagram on page 42).
- 17th** New Moon is at 7:56 p.m. EDT.
- 24th** The First Quarter Moon occurs at 7:39 p.m. EDT.
- 25th** The Moon is closest to Earth at 1:32 p.m. EDT: 229,687 miles. The Moon and Saturn form a bright pair in the evening sky (see diagram below).
- 29th** The Delta Aquarid shower peaks today: catch it before the Full Moon blots out the view.
- 30th** Mars is at its farthest from Earth: 246,000,000 miles.
- 31st** Full Moon: 5:41 p.m. EDT.

East



Saturn and the Moon
Looking south, evening

July 25

Saturn

Moon

Antares

Scorpius

The
Star Dome
shows how the
sky looks at:

Midnight on July 1st
11:00 p.m. on July 15th
10:00 p.m. on July 31st



● Sirius.
 ● Canopus.
 ● 0.0
 ● 0.4
 ● 0.8
 ● 1.2
 ● 1.6
 ● 2.0
 ● 2.4
 ● 2.8
 ● 3.2
 ● 3.6
 ● 4.0
 ● 4.4
 ● 4.8
 ● 5.2
 ● 5.6

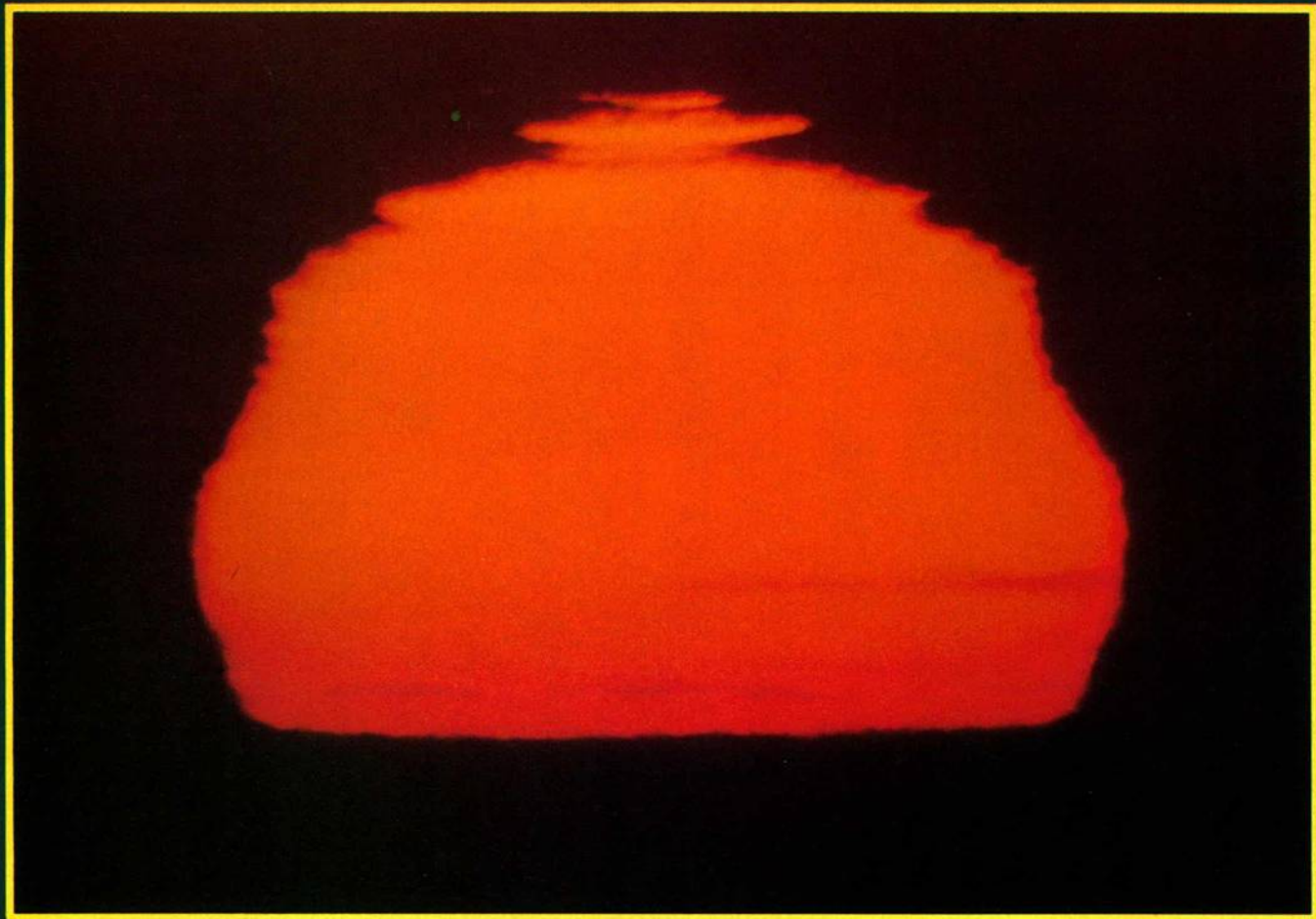
Galaxies

● Sirius
 ● Canopus
 ● 0.0
 ● 0.4
 ● 0.8
 ● 1.2
 ● 1.6
 ● 2.0
 ● 2.4
 ● 2.8
 ● 3.2
 ● 3.6
 ● 4.0
 ● 4.4
 ● 4.8
 ● 5.2
 ● 5.6

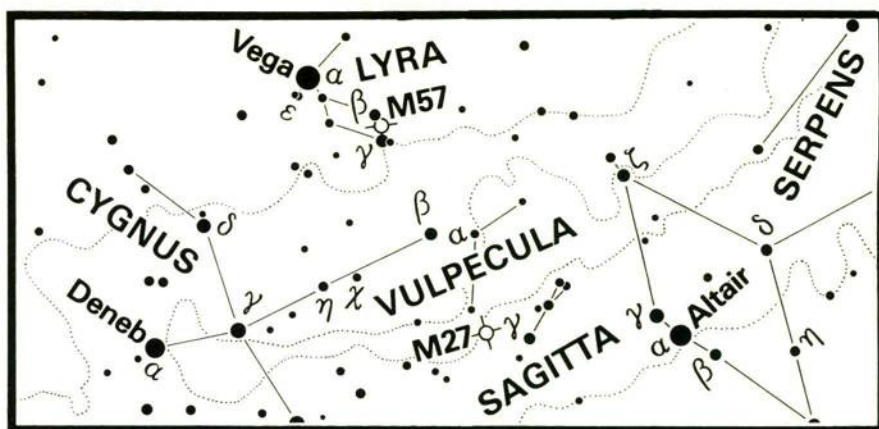
A vertical color temperature scale with labels and corresponding color swatches:

- 3,500 K (Orange)
- 5,000 K (Yellow-orange)
- 6,000 K (Yellow)
- 8,000 K (White)
- 10,000 K (Light blue)
- 20,000 K (Dark blue)

South



Top: On March 23, 1985, Jim Baumgardt shot this sunset photo from Fremont Peak, California. (An inversion layer below the 3,400-foot elevation of the peak caused the horizontal lines.) The photo was shot through a 10-inch f/5 Newtonian at $\frac{1}{250}$ -second exposure on Kodachrome 64 film; it was then enlarged 1.4 times and duplicated onto Ektachrome Slide Duplicating film 5071. Bottom: Moonrise in Death Valley was captured by Lee Peterson with a 300mm lens set at f/4.5 and a $\frac{1}{60}$ -second exposure.



shaped figure with Gamma (γ) and Sigma (σ) Librae — Saturn can be found almost between these two this month.

Alpha Librae is now close to the ecliptic. If you follow a line about 19° of ecliptic longitude to the east from Alpha Librae, you will come to a bright and easy double star just a little farther north. You have entered the territory of **Scorpius** the Scorpion and the star you are viewing is Beta Scorpii.

The Scorpion extends in a northwest to southeast direction, stretching about 30° — almost as long as Comet Halley may be when it lies parallel to, but (alas for northern viewers) south of Scorpius' figure in early April of 1986.

Between the Scorpion's head (an almost north-south line of stars) and his tail shines **Antares**. It marks the heart of this constellation and means "rival of Mars" or "against Ares" — Mars was the Roman version of Ares, the Greek god of war. Antares, at about magnitude 0.95, is the second brightest red star in the zodiac (after Aldebaran) but is only imperceptibly brighter than Spica. Since Antares is a variable star which on rare occasions has become fainter, why not check its brightness tonight?

Although Scorpius is brilliant, some of its treasures are best seen with binoculars, so try views of the wide double star Mu (μ) Scorpii and of the globular clusters M-80 and M-4 near Antares. Perhaps best of all with binoculars are two huge naked-eye open star clusters just beyond the stinger: M-6 and M-7 — the brightest and best of many pretty clusters and rich starfields in the eastern part of Scorpius.

The **Milky Way** is particularly

magnificent on July nights. It begins high in Cygnus, cascading like a waterfall of light which is broken into two individual falls, one broad and one narrow. The division starts at the dark Great Rift in Cygnus; from there, the smaller flow sweeps past Aquila and down into Serpens Cauda and Ophiuchus before trickling into invisibility. The main stream of the Milky Way pours over Aquila, forming its brightest area in dim Scutum and becoming widest across Sagittarius.

Although the Milky Way dominates dark skies, we mustn't forget that beacon of northern summer skies: the **Summer Triangle**, made up of Vega, Altair, and Deneb. The triangle's bright apex, Vega, is now approaching the sky's apex or zenith.

A Moon — or Sun — that is actually blue in color is quite possible, though extremely rare. The precise explanation for Blue Moons and Suns is complex and still being worked on, but it has long been known that these marvels are the product of diffraction by particles or droplets smaller than those responsible for coronas in clouds around the Sun or Moon. The appropriate droplets can occasionally be found in steam and in desert sandstorms — either can produce a green or blue Sun for the properly placed viewer. But making the Moon or Sun this color visible over large areas for several hours seems possible only during outbreaks of major forest fires and certain major volcanic eruptions.

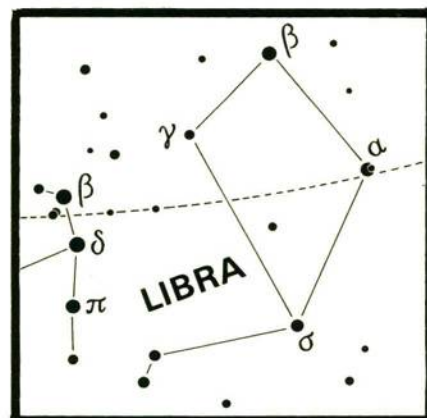
On September 24 and 25, 1950 in parts of the midwestern and northeastern U.S., the size of the particles and thickness of

Skylore

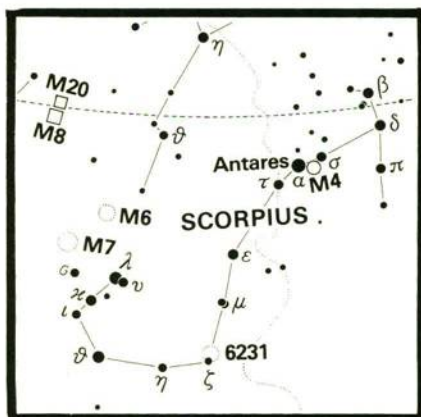
"Once in a Blue Moon" — a famous expression, but how rare is such a Moon? The second Full Moon that occurs in a calendar month is called a Blue Moon and such a Moon is uncommon, but the Moon which truly does appear blue or green is much rarer.

This month, the Moon is Full on the 2nd and the 31st. The last time we saw two Full Moons in one month was December 1982, and the next won't be until May 1988. The period between Blue Moons ranges from less than two-and-a-half to about three years.

With 31 days, July makes it relatively easy, but could there ever be two Full Moons in February? The average length of a lunar month is just over $29\frac{1}{2}$ days, therefore the month of February is never long enough to allow two Full Moon phases to occur — even in a leap year's February of 29 days. In fact, sometimes February contains just three of the major lunar phases. The last time there was *no* Full Moon was February 1961, and the next time will be February 1999. It is also possible to have just three lunar phases in a February with 29 days — this has and will happen four times between the years 1800 and 2100 — but in none of these cases is the missing phase the Full Moon.



the pall from a Canadian forest fire must have been just right. The smoke eventually reached England, still quite detectable, but not before it treated some U.S. observers to one of the rarest shows imaginable: a total eclipse of a Blue Moon! Many cases of a blue or green Sun or Moon apparently occurred after the mighty eruption of Krakatau in 1883 — as well as sightings of the Moon, Venus, Jupiter, and bright stars made vividly green by contrast with long-lasting twilight glows caused by the 1982 eruption of El Chichon.



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ASTROPHOTO OF THE MONTH



The "Dumbbell Nebula," M-27 in Vulpecula. The "ears" of the Dumbbell are seen best visually with a Lumicon UHC Filter. Photo by David Healy using a Lumicon Giant EASY-GUIDER and Lumicon hypersensitized 2415 film, 30 mic C-14 at f/6.

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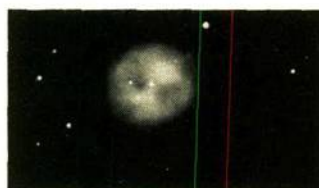
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The Owl Nebula M-97 in Ursa Major. This large faint 11th magnitude planetary nebula is seen best with a LUMICON UHC Filter. (Photo by Ron Potter on hypered 2415).

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*Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.

DEEP-SKY ASTROPHOTOGRAPHY

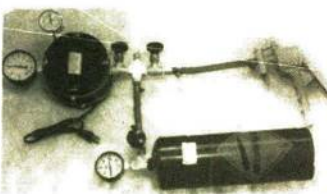
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My Quest For a Planetary Telescope

by
Robert Allen Buss

Equipment
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Amateur astronomy is addictive. There's just no other way to explain the fact that otherwise-normal people will put up with the most extraordinary things in pursuit of a hobby.

I'm a prime example. I won't take my family camping because I hate discomfort. Yet I'll brave sub-freezing temperatures or clouds of mosquitoes to resolve a colorful double star. I don't like travel, but I'll drive 1400 miles to get to a major astronomy convention. I despise the hype and come-ons of the advertising industry — but who do you find voraciously devouring the equipment ads every month? Only an addict behaves like this!

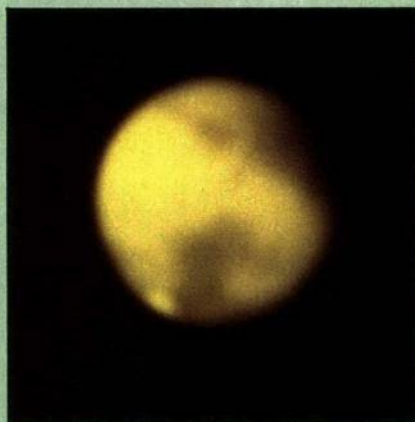
Yet I've noticed something. While my addiction to starlight is still as uncontrollable as ever, its form has changed. When I first got into the hobby, I wanted light — light, light, and still more light. To me, a 12-inch telescope was at least four times better than a 6-inch. Drinking in the soft glow of a faint NGC object was the ultimate high.

Well, I still enjoy that — but, as I said, either my addiction has changed or I have. It all started when I had the opportunity to observe a colorful double star in a small refractor. It continued when I observed a wealth of subtle markings on Jupiter in the same instrument. It began to cause me real trouble when I found I couldn't duplicate those views in my favorite short-focus light buckets — even though they had far more aperture. The search for a different kind of telescope began right then and there.

Since a 3-inch refractor had set me off, the obvious choice for my new planetary and double star telescope would have been an even larger refractor. I figured a 6-inch would be about right, since anything larger would require almost perfect seeing to perform well. But a 6-inch refractor with a long focal ratio was an impossibility. First of all, I couldn't afford one. Second, it would have been too large and heavy to carry up my basement steps, and I had neither the space, skill, nor cash to build an observatory around it. The ideal was so

far out of reach that it was unrealistic. I had to look for something else: maybe second best, but — I hoped — not too distant a second.

I quickly ruled out those off-axis reflector systems with the unpronounceable names. You can't buy them ready-made, and I had nowhere near the skill to construct one from scratch. The only scopes I ever built were Newtonians, and those I merely assembled from commercial parts. On the other hand, while my light buckets were Newtonians, they certainly weren't giving the high-power image sharpness I was after. Talk about a nightmare — what I wanted I



Mars (March 26, 1980)

D.C. Parker

couldn't have, and what I could have wouldn't work!

Then something happened — I started thinking instead of dreaming. I remembered I had seen exquisite drawings of planets made by observers using Newtonian telescopes. How did they get that image quality? I looked back at some of the captions and saw that most of them were done with Newtonians of $f/7$ or $f/8$ focal ratio. Maybe that was it! I should trade in my $f/5$ for an $f/8$. It made sense, but as I thought it over it didn't make enough sense. There was still the problem of secondary obstruction.

Newtonians use a diagonal mirror to

bounce the light from the main mirror 90° to the eyepiece. The diagonal sits right in the middle of the incoming light and causes interference, much like static in a radio. That "static," or *diffraction* as it's properly called, reduces contrast. It's like trying to listen to music through the hum of a noisy sound system.

So what's to be done? After all, you can't abolish the secondary in a Newtonian. But then again, neither could those accomplished planetary observers who used Newtonians. How were they getting such good results? I pulled some books off the shelf and started scanning. Eureka! There was an answer, a very simple and inexpensive one. While you can't eliminate the diagonal in a Newtonian, you *can* reduce its size to the point where the "static" it produces becomes negligible. That's how those observers achieved such excellent results — they used a longer-than-usual focal ratio and a smaller-than-average secondary.

But how much smaller? Happily, all you have to do is take the diameter of your primary mirror and divide that number into the minor axis of your diagonal mirror. If you come up with a number between 0.10 and 0.15, you have an excellent combination for a high-resolution, high-definition planetary telescope.

For example, let's take the traditional 6-inch $f/8$. The typical commercial version uses a 1.3" minor-axis secondary. Divide 1.3 by 6 and you get about 0.22 — not nearly good enough for what we have in mind. A 1" minor axis diagonal gives us about 0.17 — which is getting closer. But a 0.875" or a 0.75" secondary gives us 0.146 or 0.125, respectively. *That's* the range we're after. Note that the actual numbers will change with other size mirrors — with an 8-inch, for example, the minor axis of the diagonal should be no larger than 1.2".

The principle is simple, however: Reduce the size of the secondary until its minor axis is 0.15 times the diameter of the primary mirror and you have a

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diffraction-limited telescope that's excellent for planetary observing. In the case of a 6-inch $f/8$, actually building one of these was a bit difficult, since not all telescope supply firms sell 0.875" and 0.75" diagonals. It took some hunting to discover that Edmund Scientific sells a 0.875" and Telescopes sells a 0.75".

But then there's another hurdle. For technical reasons, the diagonal mirror has to intercept the entire converging cone of light from the primary mirror. Therefore when you shrink the diagonal, you must place it farther up the cone toward the focus where the beam has a smaller diameter. Yet there's an obvious limit to how far you can carry this — for instance, it's no good having the focal point fall *inside* the tube!

Whether you move the secondary forward, or the primary backward, or some combination of the two, make sure that the focus actually stays outside the wall of the tube by at least an inch. For this reason, also keep the diameter of the tube no larger than necessary — say, an outer diameter of 7" to 7 $\frac{1}{8}$ " for a 6-inch mirror. (Don't make it too tight, though — most experienced telescope users like to keep the tube wall at least half an inch away from the edge of the primary mirror.)

The average 1.25" diameter focuser is about 3" high — and many are higher. This is usually much too high to let you rack the eyepiece in far enough to reach the focus. What's needed is a "low-profile" focuser that stands only 1" to 1 $\frac{1}{2}$ " above the tube when fully racked in. I found an excellent helical one (for 1.25" eyepieces) from Telescope Systems, but they haven't been advertising lately. I notice that Lumicon now sells a 2" low-profile helical focuser (they also sell an adapter for 1.25" oculars), and Kenneth Novak has one, too.

Bear in mind that the optical layout on a 6-inch $f/8$ scope doesn't leave an awful lot of room for error. Be sure to determine the exact focal length of your mirror. (Check where the image of the Moon comes to focus and carefully measure back to the primary mirror.) Then construct either a full-size or accurately scaled-down drawing before you start chopping up tubing. Make a trip to a

Recipe for a High-Resolution, Planetary Telescope

1. Start with a Newtonian that has a medium to long focal ratio primary mirror — $f/8$ or higher, say.
2. Measure the minor axis of your secondary mirror. If it's more than 0.15 times your primary's diameter, it's too large.
3. Search telescope supply catalogs for a secondary with a minor axis no bigger than 0.15 times the primary aperture.
4. On shelf-lining paper, draw a full-size layout of your scope. Move the primary backward, the secondary forward (or both), so that the focus comes no more than an inch or so outside the tube.
5. Check to see that the secondary mirror catches all of the converging cone of light from the primary when it is placed to bring the focus the right distance outside the tube. (You may have to use a larger diagonal than you'd like.)
6. Order the right-sized diagonal, a single-vane spider to hold the secondary, and a low-profile focuser; install them.
7. Glue the primary mirror in its cell with silicone aquarium cement.
8. Line the inside of the tube with black flocked paper or mosquito netting painted flat black.
9. For reasons of stability, consider setting up the mounting (if not the entire scope) permanently outside.
10. Fill the pier with concrete or dry sand. With tripods, hang a weight low to the ground from the equatorial head.
11. Run braces from the top of the pier out to the ends of the legs.
12. Go over telescope and mounting thoroughly, looking for loose connections, gears that need lubrication, etc.

grocery store or a well-stocked hardware store and look for a roll of white shelf-lining paper. These run about 50 feet long and a foot wide — ample for laying out the scope's diagram full-size.

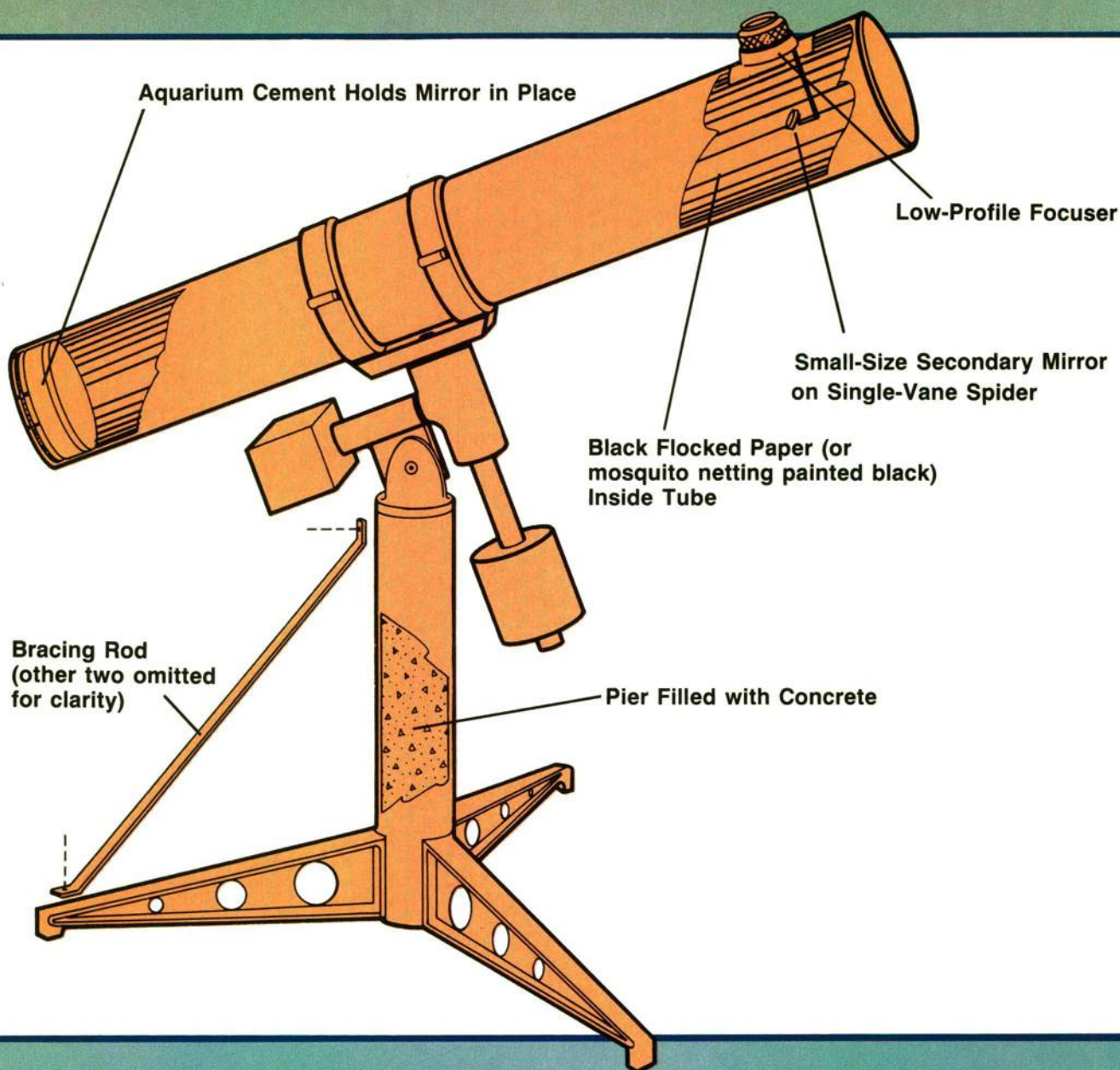
Do a very careful paper layout, then double-check the size of the secondary: measure the distance from the focal point down to the center of the diagonal. Take this number and divide it by the f /ratio of the primary; the result is the diameter of the light cone at the position of the secondary. *The diagonal mirror must not be any smaller than this.* You may find that due to an assortment of reasons — a large tube diameter, for example, or a fast-converging light cone — the numbers force you to use a larger diagonal than you'd like. Should this happen, give in and don't fight it — or you may worsen your scope's performance. In general, low f /ratio scopes are at a severe disadvantage in the small diagonal/planetary telescope business since they afford the least room for adjustment.

Another area to improve is the "spider"

that holds the secondary. The average spider often has a mirror mount larger than the diagonal — and remember, it's the total obstruction that counts. I got around this by using a single-vane diagonal holder. Since the diagonal mirror is small and lightweight, the full-blown four vane support isn't necessary.

Some snags came between my discovery of how to build a planetary Newtonian and its actual construction, but fortunately, they were manageable and I got the scope assembled and collimated. It was time to try it out. Not to keep you in suspense — had the results been poor, obviously you wouldn't be hearing about it — the telescope exceeded my expectations. The contrast and sharpness of planetary images are excellent. I've seen subtle details similar to what the best planetary observers have drawn. I've split 1 arc-second doubles with enough black sky between them to drive a truck through.

Henry Paul's book, *Telescopes for Skygazing*, says that such a telescope will



perform as well as a 5-inch refractor and may do even better on nights of excellent seeing. Although I've never tested my 6-inch $f/8$ planetary Newtonian next to a 5-inch refractor, I have been able to compare it with an excellent 4-inch refractor. When the seeing was steady, my 6-inch beat it easily.

Now a word or two on mountings — no matter how good your optics, the final image depends critically on having a sturdy and smoothly-operating equatorial mounting. Tweaking up your scope's optical performance is wasted if you turn right around and stick it on a mounting that jiggles and dances for 5 to 10 seconds every time you touch the focuser. If you can afford it, buy a mounting that's intended for the next largest size of telescope: put your 6-inch on the mount for an 8-inch, or even a 10-inch. This keeps the telescope load very light relative to the mount's design limit — and steadier images and smoother operation will almost certainly result.

Failing that, take a critical look at the

mounting you have and give serious thought to setting it up permanently outside. Then you can either fill the pier with concrete or dry sand, or put the equatorial head on a rock-solid custom-built pier. A shed-observatory that covers the complete scope is a delightful luxury, but you can get by with a weatherproof box that protects the mounting alone.

If portability is essential, look for ways to beef up the system. With a tripod mounting, suspend a weight low to the ground from the equatorial head. This adds mass and helps damp vibrations. If you have a pier-mounted model, run triangular braces of small angle-irons or electrical conduit from the top of the pier (just under the equatorial head) out to ends of the three legs — this adds great rigidity. Are the clutches, locks, and slow-motions in proper adjustment? Is the worm gear on the drive snugged up to minimize backlash? A judiciously-applied squirt of WD-40 can ease sticky controls. And so on. Haul out the owner's manual to refresh your memory, and then give the

entire telescope a careful look-over.

I've been using this telescope for three years and have made some further optical improvements. I removed the metal clips from the mirror cell and glued the primary in place with aquarium cement. Not only does this flexible rubbery stuff hold well, it eliminates diffraction from the mirror clips. I'm now thinking about lining the telescope with mosquito netting painted flat black to reduce scattered light further. And when my mirrors become dingy, I'm going to spend extra for enhanced coatings. This telescope is good enough to lavish that kind of attention on.

I'm delighted with my 6-inch planetary Newtonian. It may be second-best, but it's sure not second by much.

Robert Allen Buss is an Episcopal clergyman in Dickinson, North Dakota. He has been an active observer for eight years, and especially enjoys the challenge of observing with small instruments. His last article in ASTRONOMY was "In Defense of a Classic," which appeared in the October 1984 issue.

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ASTRONOMY

Reviews

The General History of Astronomy, Vol. 4: Astrophysics and Twentieth-Century Astronomy to 1950, Part A

Owen Gingerich, ed.

212 pages, hardcover, \$29.95

Cambridge University Press (1984)

Don't let the title scare you — this isn't another history of astronomy for technofreaks. Although historians and astronomers will appreciate it, the average reader will certainly enjoy it also. Eighteen experts in astronomy from eight countries contributed 11 chapters — all aimed at a general audience. The result is an amazingly coherent, well-written, and beautifully-illustrated book.

Credit must go to Owen Gingerich, a former solar physicist and well-known historian of astronomy at Harvard, and to Michael Hoskin of the University of Cambridge — the general editor for the series. Volume 4, part A deals mainly with the birth of astrophysics and the rapid growth of major observatories between 1850 and 1950, when large telescopes, supporting instrumentation, and physical theory all combined to produce fantastic advances and new discoveries that revolutionized astronomy and changed our concept of the universe. This was certainly astronomy's Golden Age — but the end is nowhere in sight.

A welcome feature is the book's large number of illustrations — almost 80 in all — which have never been previously published. They bring the book to life and give the reader rare insights. For me, notable contributions were John Lankford's chapter on the development of astronomical photography between 1880 and 1900, and David DeVorkin's excellent account of the origin of the Hertzsprung-Russell diagram.

The late Alexander Mikhailov, long a director of the world-famous Pulkovo Observatory near Leningrad, presents an all-too-brief but still picturesque history of that institution in chapter 7. In chapter 8, it was a pleasure reading about the 100-inch Hooker and solar tower

telescopes at Mt. Wilson — but sad, too, because they have recently been closed.

One complaint — some chapters seem to have been edited severely, leaving the reader thirsty for more detail. (Perhaps this explains why the editors provided references at the end of each chapter.) An appendix compiled by Barbara Welther lists the world's largest telescopes, both refractors and reflectors, that were still in use up to 1950. It nicely compliments Albert Van Helden's two chapters tracing the scientific, technical, and — all important, even a century ago! — financial influences that led to the establishment of the world's major observatories between 1850 and 1950.

Since it's next to impossible to squeeze the entire history of astronomy between the pages of a single volume, the editors divided this tremendous undertaking into four:

Vol. 1, *Astronomy from "Antiquity to the Renaissance,"* Vol. 2, *"Planetary Astronomy from the Renaissance to the Mid-nineteenth Century,"* and Vol. 3, *"Stellar Astronomy, Instrumentation, and Institutions From the Renaissance to the Mid-nineteenth Century."*

(The period since 1950 will have to await future astronomical historians.)

If the other volumes are as well-written and well-illustrated as this one, the series promises to set a high standard — and I can't wait to read them. The editors of *The General History of Astronomy* should be congratulated on a job very well done. *Don Trombino.*

Renaissance

100mm f/5.5 refractor, \$1325

equatorial mounting, \$395

TeleVue Optics, Inc.

If you're looking for a handsome and versatile small telescope, and don't mind shopping around a bit for a mounting that matches its quality, the Renaissance is an excellent choice. This 4-inch aperture f/5.5 refractor is a four-element system

designed for excellent wide-field and high-magnification viewing. Finished in brass and black anodized aluminum, the Renaissance is a show stopper among current commercial telescopes.

Our loaner instrument, serial number #1018 (presumably the 18th of these handsome multi-purpose instruments built), showed just a few minor "bugs" that had not yet been fully worked out. Most annoying was looseness in the focuser: to avoid marring the focuser tube finish, the outer sleeve is fitted with several Teflon inserts, but they were not tight enough so the focuser tube tended to wobble. We were assured that this problem is absent in later instruments.

Optically, the Renaissance is a four-element refractor. The two front lenses are 4 inches in diameter and have a considerably longer focal length than the f/5.5 of the system. Two smaller elements near the back of tube reduce the focal length and give the designer freedom to provide excellent imagery over a wide field of view. These extra elements do not reduce secondary spectrum below the values found in typical longer-focus doublet refractors.

The short focal length of the Renaissance gives it unusual versatility. With roughly half the physical length and one-third the focal length of the classic 4-inch f/15 refractor, the Renaissance fits in the back seat of a small car and can be maneuvered indoors without danger to itself or the woodwork. More significantly, though, the short focal length means that the instrument can be used as an RFT or as a high-power telescope merely by choosing an appropriate eyepiece.

Making use of the full range of magnification — from 14x (where the Renaissance serves as its own finder) to high powers suitable for splitting doubles and viewing planetary detail — calls for a full set of eyepieces. The following eyepieces (from TeleVue) might make a nice set for the Renaissance: a 40mm Wide-Field (\$265), 26mm and 17mm Plossls (\$80 each), a 13mm Nagler (\$235),

a 7.4mm Plossl (\$80), and a 4.8mm Nagler (\$140). If you must reduce the number in the set, try a 2.5x Barlow (\$80) in lieu of the Naglers, or a 9mm Nagler (\$180) if you're flush. However you do it, the eyepieces constitute a substantial investment above and beyond the cost of the basic instrument.

Like most doublet refractors, the Renaissance displays significant secondary spectrum. This is especially obvious when viewing bright objects such as Venus or Sirius, where the planetary or stellar image is embedded in a purple halo. On fainter stars, the star image appears green or yellowish because red and blue light falls outside the image. Serial #1018 showed slight flare to one side of the image, probably the result of a small error in assembly or alignment. While this did not prevent its cleanly resolving Epsilon Lyrae and Castor, its presence hampers viewing low-contrast planetary detail on extended objects like Saturn. Overall, the image quality exceeds that of Schmidt-Cassegrains with comparable aperture, but is not quite as good as a conventional f/15 refractor, nor can it match the imagery of a TCT or even some of the better 4-inch f/10 Newtonians we've used. In all fairness, though, the Renaissance is more versatile than any of these three.

One small feature we particularly liked is the screw-on lens cover. This provides positive protection to the front element of the lens — unlike the slip-off type, which sometimes falls off on its own. The machining and workmanship appear to be excellent throughout, and assembly appears carefully done, barring the minor adjustment problem in the focuser which we were able to fix ourselves.

One note on the brass tube: we expected that fingerprints would soon mar the finish, but they do not. Light rubbing with a soft cloth restores the tube's appearance quite nicely.

The optional equatorial mount supplied with the Renaissance is the system's weakest part. It is a Japanese import of a style popular about 10 years ago. In looks and performance, it simply doesn't compare with the Renaissance. The worst problem stems from mechanical hysteresis and weak action in the R.A. and declination clamps. This sloppiness made locating and centering objects for high-power observing considerably more difficult than it should have been. Another problem, albeit minor, is the adapter that connects the Renaissance to the mount. It doesn't fit well. The ¼-20 nuts that attach the telescope are hard to run on because the mount's declination pointer interferes with the nut. More appropriate for the Renaissance would be the Mizar equatorial mount currently supplied with Medea's JSO-12B or the Celestron Super Polaris mount. Either would allow the observer to exploit the Renaissance more fully.

While the Renaissance has only a 4-inch

aperture (and thus limited light-gathering power by today's standards), its ability to function effectively at low, medium, and high magnifications is outstanding. Though rather expensive when the cost of eyepieces is included in the price, this is not a problem if you already own a good set. We now hope TeleVue will introduce an equatorial mounting as handsome as the Renaissance itself. *Richard Berry.*

Asimov's Guide to Halley's Comet

Isaac Asimov

118 pages, hardcover, no price given
Walker and Company (1985)

Far beyond the planetary limits of the solar system lies a cloud of cosmic debris, eons old. Millions of ancient relics, dating from the birth of the solar system, orbit the Sun in a dim, cold twilight as far as a light-year out in all directions. Passing stars may send one of the frozen fragments sunward in an elongated orbit to become a comet. Depending upon its trajectory, the comet may sweep around the Sun once and then vanish forever — or it might become a periodic visitor to the inner solar system, returning at predictable intervals. The most famous of these intermittent visitors is, of course, Halley's Comet.

Accompanying the great surge of interest in the famous comet's return is an equally-predictable flurry of new comet books. One of the better ones, aimed at an interested but astronomically-naïve audience, is *Asimov's Guide to Halley's Comet*.

Long known as a popularizer of science and one of the most prolific writers of any kind, Asimov here strikes a happy balance of astronomy, history, and simplified celestial mechanics with an interesting blend of superstition and comet lore.

A potential buyer should note, however, that the title is misleading — only about 30 pages deal directly with Halley's Comet. This isn't necessarily a shortcoming, since to understand Halley you must first learn something about comets in general. The book is avowedly non-technical; in fact, most readers of *ASTRONOMY* won't find much new in it. But for its intended audience (that uncle of yours who's been pestering you about the upcoming return), the book is worthwhile and puts comets into their perspective as members of the solar system.

To help keep the general reader's interest, Asimov has thrown in numerous sidelights and anecdotes. In ancient times, for instance, women often displayed mourning by loosening their hair and allowing it to stream freely. This display of negligence served as a public announcement that they were too distraught with sorrow to care for their appearance. From this, Asimov points out, it was only a short step to equating "long-haired" comets to grief and catastrophe.

Superstition eventually gave way, however, and in the 15th century the rudiments of research into these ephemeral visitors began. Yet Asimov notes that the earliest "research" was anything but methodical and rational.

In 1711, an English mathematician refigured Comet Halley's orbital period and came up with 575 years. He immediately published some startling information that directly linked the torrential rains of Noah's time with the comet. For good measure, he predicted a future return of the comet would cause Earth to fall into the Sun and burn.

A century later, a spectacular comet swept across the heavens at the same time that a particularly fine vintage wine was bottled. According to the author, "Comet Wine" commanded premium prices until the supply was exhausted.

A typical Asimovian compilation, this book will stimulate the imagination of anyone in the general public who is interested in comets. It has many black and white photographs — one on nearly every other page — which add to the volume's popular appeal. If you want a book that deals comprehensively with Halley's Comet, or comets in general, look elsewhere. But if you're new to astronomy and want a simplified introduction to these interesting solar system inhabitants, this is a good place to start. *Gail O. Clark.*

Contemporary Astronomy, 3rd edition

Jay Pasachoff

515 pages, paperback, no price given
Saunders (1985)

"*Contemporary Astronomy* is written for students with no background in mathematics or physics . . . In my own classes I have found that many students take astronomy because they have heard a bit about black holes or some other fascinating phenomena and want to know more. I have organized this [textbook] to plunge right into real astronomy from the beginning . . ."

Man in Space: National Historic Landmark Theme Study

Harry A. Butowsky

About 600 pages, paperback, \$34;
microfiche, \$4.50
NTIS (1984)

[Order as PB 85 107233 from: National Technical Information Service, Springfield, VA 22161]

Compiled for the National Park Service, the purpose of the *Man in Space* study was "to evaluate all resources which relate to the theme Man in Space and to recommend certain of these resources for designation as National Historic Landmarks." Four sub-themes formed a general framework for the study: technical foundations before 1968, the Moon-

landing program, exploration of the solar system, and scientific and communications satellites. Butowsky whittles a very large list down to some 24 sites — including four NASA wind tunnels, a Saturn 5 rocket at Huntsville, Alabama, and the Rogers dry lake (a Shuttle landing site) at Edwards AFB — which he feels are the best-preserved and richest in historical associations.

Sky Catalogue 2000.0

Volume 2: Double Stars, Variable Stars, and Nonstellar Objects

Alan Hirshfeld and Roger W. Sinnott, eds.
385 pages, hardcover, \$49.95;
softcover, \$29.95
Sky Publishing (1985)

Sky Catalogue 2000.0, volume 2, is a reference work listing data for nearly 12,000 double and multiple stars, over 2,000 variable stars, and more than 5,000 clusters, nebulae, and galaxies. Special sections provide information on quasars, X-ray sources, radio sources, suspected variable stars, spectroscopic binary stars, and visual binaries. A 50-page introduction details astronomical nomenclature, the catalogue, and how to use it. (The first volume of *Sky Catalogue 2000.0*, covering stars as faint as magnitude 8.0, was published in 1982.)

Computer Star Finder

For Apple II+ and
Apple IIe microcomputers
One 5¼" floppy diskette with star charts,
no price given
Hubbard Educational Software (1984)

This is a computer star map program for Apple micros.

Planets and Their Atmospheres

John S. Lewis and Ronald C. Prinn
470 pages, hardcover, \$59
Academic Press (1984)

Part of the "International Geophysics Series," this book — aimed at a professional readership — examines in detail the chemical compositions and behavior of our solar system's planets, concentrating on their origins and development over the past several billion years.

Out of the Cradle: Exploring the Frontiers Beyond Earth

William K. Hartmann, Ron Miller, and Pamela Lee
190 pages, hardcover, \$19.95;
softcover, \$11.95
Workman (1984)

Through the visions of space artists, Hartmann, Miller, and Lee explore the

possibilities for exploring the solar system and capitalizing on its resources in the future.

Sympathetic Vibrations

K.C. Cole
352 pages, hardcover, \$16.95
William Morrow (1984)

Subtitled "Reflections on Physics as a Way of Life," this book outlines methods and thought processes used in physics and science in general. The author discusses everything from relativity to quantum mechanics to vector forces to simply observing what's going on around you.

Universe in the Classroom

Andrew Fraknoi
269 pages, softcover, \$8.95
W.H. Freeman (1984)

This guidebook references books, articles, and visual aids of use to classroom instructors in teaching astronomy. It is designed to accompany William Kaufmann's textbook *Universe*.

Halley's Comet

Donald Tattersfield
164 pages, hardcover, no price given
Basil Blackwell (1984)

After recounting historical information on Edmond Halley and his comet, Tattersfield outlines the basics of cometary orbits and compositions. He also predicts how bright Halley's Comet will appear and the best times for observing the comet.

Astronomy and History: Selected Essays

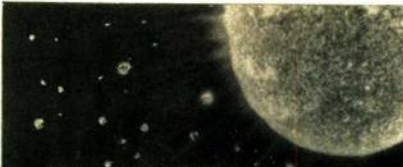
O. Neugebauer
538 pages, softcover, \$22
Springer-Verlag (1983)

This tome is a collection of essays addressing Egyptian, Babylonian, Greco-Roman, Medieval, and Renaissance astronomy. Topics include magnitudes of early lunar eclipses, the alleged Babylonian discovery of precession, early history of the astrolabe, and ancient astrology.

Seeing Earth: Literary Responses to Space Exploration

Ronald Weber
138 pages, hardcover, no price given
Ohio University Press (1985)

This book investigates various writers' attitudes toward and perceptions of space travel. Featured are excerpts from Tom Wolfe, Carl Sagan, James Michener, Norman Mailer, Ken Kesey, Ray Bradbury, and Ben Bova.



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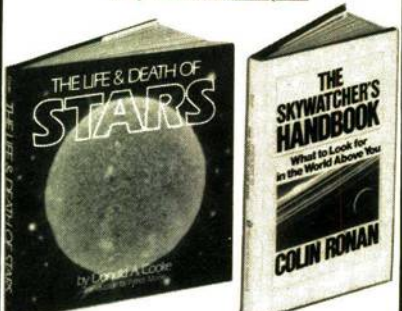
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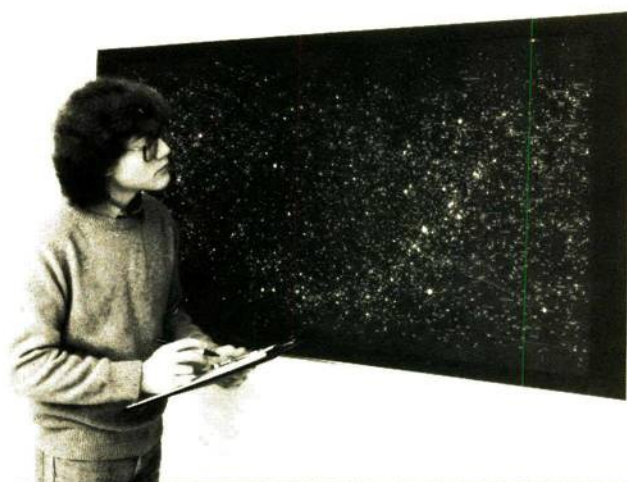
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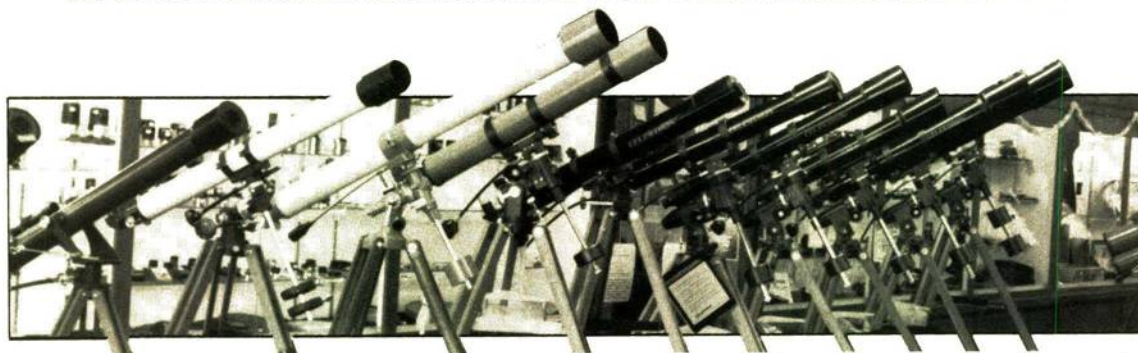
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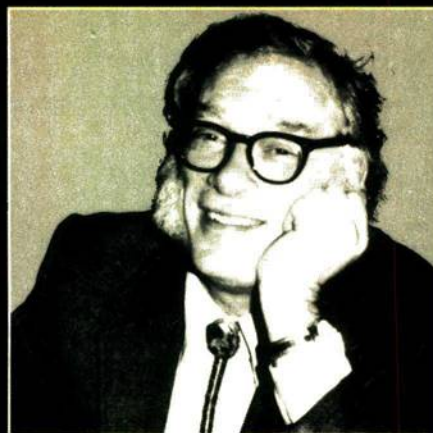
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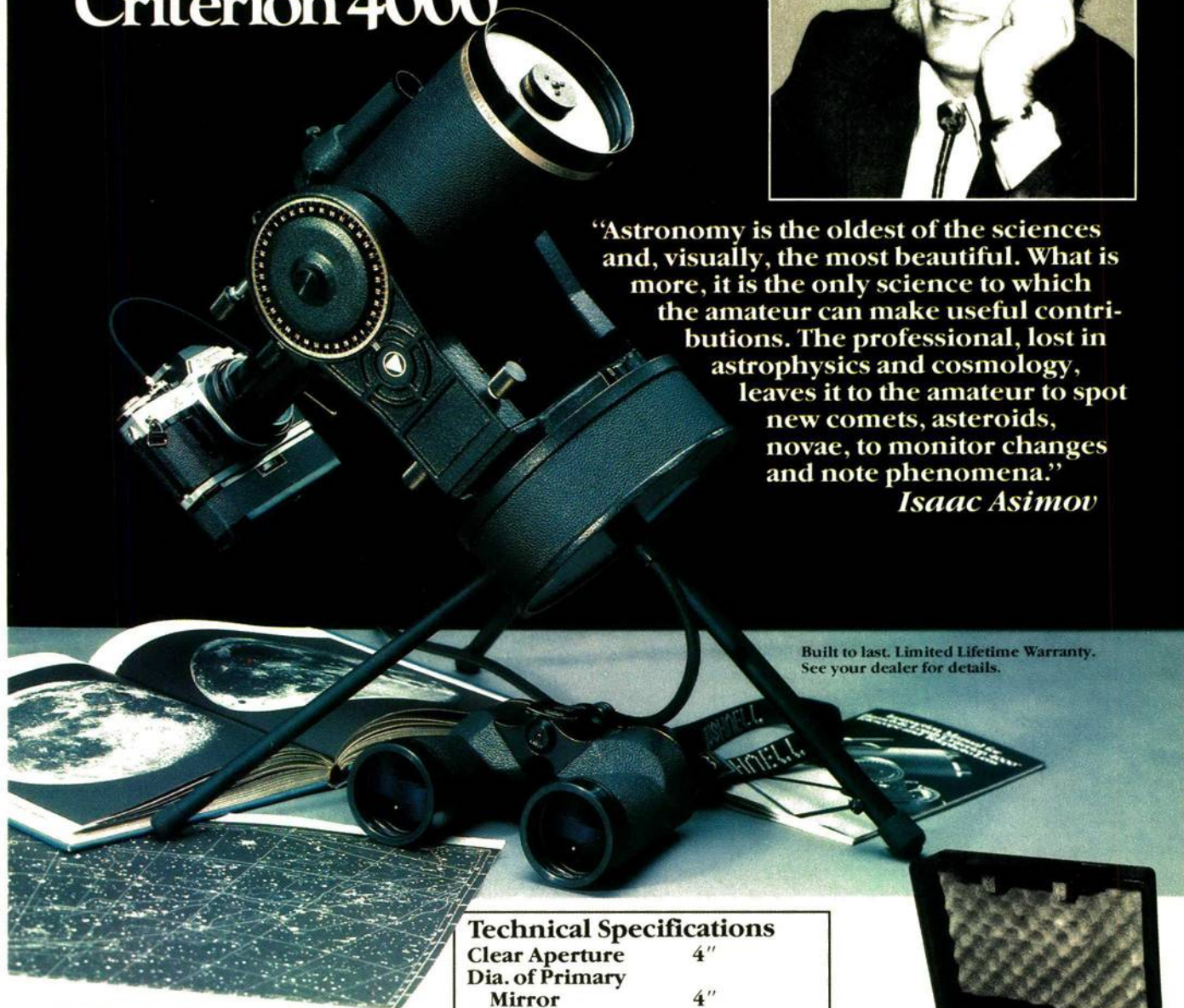
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II Zw 23: A Late-Blooming Galaxy

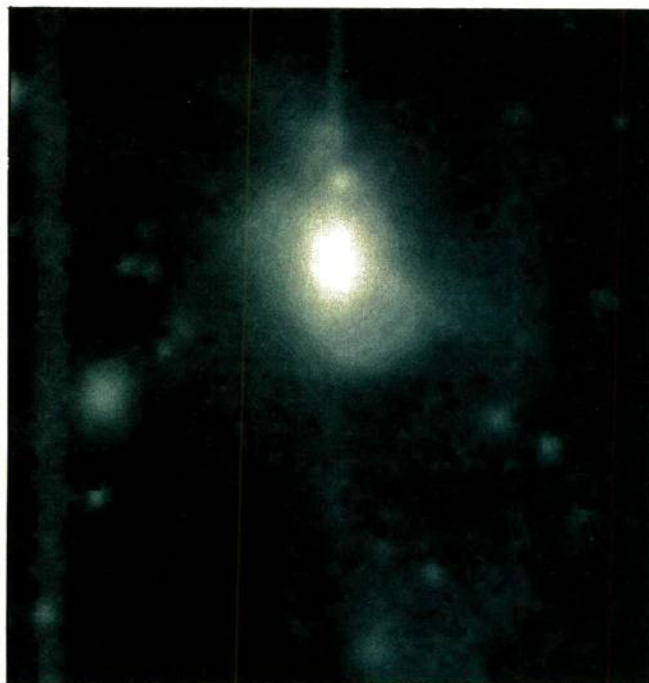
A "late-blooming" galaxy in the early stages of formation is offering astronomers a rare chance to observe events almost as they were when most galaxies formed billions of years ago. The galaxy — designated II Zwicky 23 (after the late Caltech astronomer Fritz Zwicky) — lies some 175 megaparsecs away toward the constellation Taurus. Studies of it should help clarify galactic geometry, angular momentum, and how and when galaxies acquire a magnetic field.

At the winter meeting of the American Astronomical Society in Tucson, Arizona, astronomer William C. Keel of Kitt Peak National Observatory reported on II Zwicky 23. Keel said that while II Zw 23 is not the only late-forming galaxy in the sky, it is an uncommonly vivid case in which a system is "just getting around to collapsing into a normal galaxy."

Early observations of II Zw 23 reveal a compact, blue, elliptical galaxy from which optically-visible jets of matter are shooting into space. According to Keel, it actually is just the reverse: He describes it as a "hairy compact" galaxy with irregular filamentary extensions "somewhat resembling a spider, overall." Detection of these filaments led to the present interpretation that the galaxy is collapsing from a cloud of neutral hydrogen and experiencing its first galaxy-wide episode of star formation. By contrast, the galaxies which formed billions of years ago have already undergone several bursts of star formation, effectively erasing the primeval characteristics that Keel believes may still be detectable in II Zw 23.

"What we see here is very much like what should have gone on early in the history of all galaxies," says Keel, "with some differences. The universe is much older now. Ten or 15 billion years ago there would have been some small, dim galaxies with lots of gas clouds around them. Primeval galaxies would have been much closer together, so that gas from nearby galaxies would have been more important. Stars from the remnants of those galaxies are now so faint and few, we can hardly find a trace of them. They are lost among the brilliant newcomers."

Keel's estimate of the current "spectacular" rate of star formation in II Zw 23 suggests that it has been producing at least 35 solar masses of stars per year for something like 100 million years — long enough to



NOAO

have spawned more than a billion solar masses. During this period, he infers that the rate of star formation has increased 10 to 100 times over; this suggests II Zw 23 is in the midst of an enormous, slow burst of star formation in which most of its atomic gas will be converted into stars. If it continues at the present rate, the cloud of neutral hydrogen feeding into the galaxy will last about a billion more years.

"We are uncertain how much star formation occurs as material is falling into the galaxy," Keel says. "Most infalling material doesn't turn into a star until it gets into the main assembly. Most of it is hydrogen; there is very little heavier material. But then, as you look toward the center of the galaxy, where you have supernovae popping, you can see the heavier elements increase. Both image processing and velocity studies indicate [II Zwicky 23] will finally settle into a spiral galaxy."

According to Keel, radio-frequency radiation from the galaxy appears to be nonthermal — in other words, it is synchrotron radiation produced by particles spiraling across large-scale magnetic fields. The particles may be accelerated by supernovae remnants. Says Keel: "Radio observations suggest large-scale magnetic fields in the infalling matter. This means the magnetic field was in the hydrogen cloud before infalling began, and suggests the field may be 'frozen' into the galaxy by material falling into it."

But the bizarre young galaxy raises as many questions as it answers. "I

can't tell if the amount of stuff I see flying in through these filaments is all the matter coming into the galaxy," explains Keel. "I wonder how much is there in addition to newly-formed stars. The least startling assumption at this point is that this object could have been around, as a galaxy, all this time, and is only just now beginning to condense into stars. But why, all of a sudden, should hydrogen start clumping up and falling into the galaxy?" One possibility, according to Keel, is that an apparent companion galaxy some 100 kiloparsecs away has exerted stress on the gas cloud, causing it to condense and fall into the newly-forming galaxy.

Are Galaxies Dead Quasars?

Astronomers analyzing light from the centers of nearby galaxies recently uncovered evidence that many galaxies are "dead quasars" because they display weak emissions of quasar-like energy from their nuclei. These findings support the idea that most, if not all, galaxies — including our own Milky Way — were quasars when the universe was young. Previous studies by astronomers at Kitt Peak and Lick Observatories revealed the telltale fingerprints of quasars in the spectra of several galaxies, but this latest study is the first to clearly display that many galaxies have this characteristic.

Quasars are basically small, irregularly variable, and starlike objects that astronomers believe are very distant, extremely energetic, and powered by supermassive central black holes. Lying between 300 megaparsecs and four billion parsecs away, they are brilliant at such great distances due to material being superheated as it falls inward toward a black hole, which emits intense X-ray, radio, and optical radiation. The quasars we see appear as they did long ago, leading astronomers to believe that after quasars used up the available fuel, their energy waned and they became normal galaxies.

Astronomers Alexei Filippenko of the University of California at Berkeley and Wallace L.W. Sargent of the California Institute of Technology reported their findings in the March issue of the *Astrophysical Journal Supplement*. They used the 5-meter Hale telescope at Palomar Observatory.

Filippenko and Sargent surveyed 75 bright galaxies between four and 18 megaparsecs from Earth, measuring the spectra from their nuclei. They then used a computer to subtract the incoming light from stars around the nuclei using either spectra of similar galaxies as a standard or subtracting the spectrum of the entire galaxy away from its nucleus. "The result was that, in 19 to 28 of the cases, the emission lines characteristic of quasars became evident," said Filippenko. "The reason for the range is that we are still analyzing the data, and since these emissions are only a few percent above the background, they're extremely hard to detect. Many, if not most, of these galaxies could be dead quasars, but the spectral lines may be just too weak for us to see."

He added, "Detecting these quasar-like emissions amidst the starlight from the galaxies is like trying to see stars in the daytime on Earth. Their light is there, but it's swamped by the huge amount of scattered light from the Sun." According to Filippenko, the galaxies surveyed were "best case" galaxies, with bright centers which the astronomers felt would likely yield detectable quasar-like activity. The galaxies included the bright spiral M-81 in Ursa Major, which is structurally similar to the Milky Way. The astronomers are now looking at other observations, which include M-31, the Andromeda Galaxy. "We can't examine our own Galaxy, because the center is obscured by clouds of gas and dust," said Filippenko. "But if our Galaxy was once a quasar, it was a rather modest

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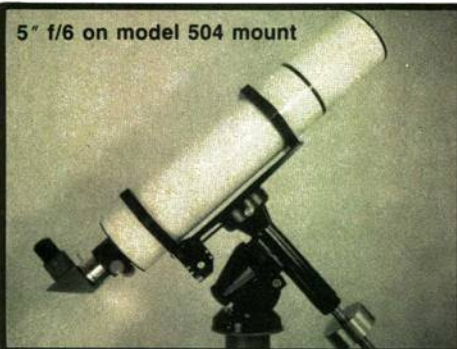
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one, containing a black hole with a mass of only about five million suns."

The 75 galaxies are just a beginning. Over the next few years, the astronomers will look at an additional 425 galaxies using the 5-meter telescope and will attempt to look at even more using the Hubble Space Telescope, to be launched in 1987. Said Filippenko: "The Space Telescope will have extremely high spatial resolution, and will enable us to detect even smaller quasars in the centers of galaxies than is possible with the 5-meter reflector. If we can do such a study with the Space Telescope, we may end up with an avalanche of galaxies that are dying quasars."

Soviet Spacecraft Carries American Instrument Toward Halley

A comet dust analyzer designed and built at the University of Chicago is being carried toward Halley's Comet aboard the Soviet Union's Vega spacecraft, launched December 15, 1984. An identical instrument was launched aboard a second Soviet spacecraft on December 21, 1984. This is believed to be the first U.S.-built interplanetary experiment ever carried aboard a Soviet spacecraft, and will be the only entirely U.S.-built experiment on any scheduled mission to Halley's Comet.

The comet dust analyzer was invented by University of Chicago physicist John Simpson, and the collaboration was the result of an invitation to Simpson from the Space Research Institute of the U.S.S.R. Academy of Sciences.

"This opportunity seemed important not only for its scientific value," Simpson said, "but also as a demonstration of the cooperative, peaceful space exploration which can be achieved between our two countries." He added that it "is also exceptional in the degree to which I was able to control our experiment and in the level of cooperation between technical staffs of the two laboratories."

The instrument, about the size of a shoe box, will measure the number and mass of Halley's dust particles as the Vega spacecraft passes by the comet. Because the Vega craft will be the first of five spacecraft to reach Halley, the findings on dust density will be used to determine hazards of closer approaches by the second Vega craft as well as probes to be sent by the European Space Agency and Japan. The analyzer is much

more sensitive than previous instruments and can measure dust densities about 1000 times higher. It is sensitive to particles as small as one-tenth of a trillionth of a gram in mass — the size of matter believed to have originated during the formation of the solar system.

Simpson will regularly receive tapes of both instruments' findings as they travel through interplanetary space to meet Halley in March 1986. The data will be fully accessible to the international scientific community, he said.

The development of the new detector began in the spring of 1983, when Simpson proposed a new concept for measuring comet dust. It was successfully tested over the next few months by one of Simpson's associates, Anthony Tuzzolino, senior research associate in the University's Enrico Fermi Institute. At a scientific meeting in Holland in September 1983, Simpson described how these findings could be applied to a mission to Halley's Comet. Within a month, he was invited to build detectors for the Soviet probes. Other instruments aboard the probe had been chosen three years earlier and were already being delivered to Moscow by that time.

Work on the instruments began on March 5, 1984 and the prototype was delivered on May 7. "We really had to make an extraordinary effort to build these instruments," Simpson said. "We worked on an astonishingly short time scale for a space mission." A telex "hot line" was established between the two laboratories to improve communications while integrating the Chicago instruments into the Soviet spacecraft.

A Younger Universe?

The universe is a relatively young 12 billion years old and not the 20 billion years old that many astronomers have thought, claim University of Arizona astronomer Marc Aaronson and collaborator Jeremy Mould of the California Institute of Technology.

Reducing the age of the universe also reduces the size of the universe, placing the most distant observable objects 12 billion light-years away rather than 20 billion, says Aaronson.

The size and age of the universe are determined mainly by measuring redshifts in the spectra of light from galaxies. The smaller and fainter — the more distant — a galaxy appears, the greater the redshift in its spectrum. Astronomers can calibrate

redshift-derived distances by establishing the distances to the nearest galaxies, using classical astronomical methods such as variable star luminosities and, more recently, by comparing a galaxy's luminosity at infrared wavelengths with the motions of molecular hydrogen clouds within it.

The redshift/distance relation — known as the Hubble Law, after Edwin Hubble who discovered it in the late 1920s — also reflects the rate of expansion of the universe. The rate itself, called the Hubble constant (H_0), is expressed in kilometers per second per megaparsecs of distance. The larger this figure, the smaller and younger the universe.

Aaronson says the calibration calculations can be erroneous if the motion of objects at the "local" scale is misunderstood. Consequently, he and Mould have spent considerable effort working out a luminosity/redshift relation for nearby galaxies and clusters of galaxies. Their results show that the Local Group of galaxies — which includes the Milky Way, and about 20 other galaxies — is moving at 333 km/sec toward the Virgo Cluster, the center of our local supercluster of galaxies. In addition, they say the entire local supercluster, containing several thousand galaxies, is moving toward the Hydra/Centaurus supercluster at 310 km/sec.

According to Aaronson, incorporating the new findings into the calculations gives a value for H_0 equal to 90 km/sec/Mpc and an age for the universe of 12 billion years. Many astronomers have maintained that H_0 is closer to 50 km/sec/Mpc — and that the universe is 20 billion years old.

What does this mean for cosmology? When Hubble first determined the constant, he assigned it a value of 500 km/sec/Mpc. Since then, as the cosmic distance scale has been examined, tested, and refined, the value of H_0 has dropped steadily, reaching the present consensus, 50. At the same time, the estimated age of the universe has grown from 2 billion years to 20 billion.

But over the past 20 years, a significant number of astronomers have been arguing that a Hubble constant of 50 is too low — that 100 comes closer to fact. Their work, like that of Aaronson, Mould, and their collaborators, is solidly based on studies of the local supercluster.

The problem faced by both the "50" camp and the "100" camp is that while the local supercluster results look good (implying a smaller, younger universe), there is also good evidence from stellar

evolution theory that globular clusters are between 12 and 15 billion years old. Their parent galaxies — and the universe itself — must be much older still. This supports the older, bigger universe model.

So who's right? The jury's still out — and both camps hold firm to their values for H_0 , study their data, and look forward to the launch of the Space Telescope. *Tom Kovach.*

Elliptical Galaxies Have Hot X-Ray Coronas

Evidence that some of the so-called missing matter of the universe may be found in great dark halos surrounding galaxies has been uncovered in X-ray observations of elliptical galaxies. While the exact nature of this material still remains a mystery, the new data offer an ideal means for probing the forces of gravity in regions that extend far beyond the visible luminous matter seen in conventional optical images of such galaxies.

The analysis of X-ray emission from 55 elliptical galaxies by William Forman, Christine Jones, and Wallace Tucker of the Smithsonian Astrophysical Observatory shows that a hot gaseous envelope, or corona, may be a common feature of all elliptical galaxies.

Previously, it had been believed that gas originating from individual stars was expelled from the galaxy by supernova explosions and thus lost into intergalactic space. Indeed, optical images of these objects are notable for their lack of any gas or dust between the stars.

The X-ray evidence for extended halos now suggests that some of the hot gas remains trapped in the galaxy's surroundings. The gas is apparently bound to the system by the same gravitational forces that hold the galaxy together. Similar halos are well-established for spiral galaxies — systems such as our own Milky Way — but these are the first extensive observations of coronae around ellipticals. (see "Cosmic Pinwheels: The Spiral Galaxies," *ASTRONOMY*, May 1985).

With a temperature of some 10 million degrees, the gas is invisible to optical telescopes but emits copious amounts of X-rays. These were recorded by the imaging telescope aboard the Einstein Observatory, a NASA satellite that operated between 1978 and 1981.

Forman, Jones, and Tucker estimate the total mass of a typical elliptical galaxy and its halo is

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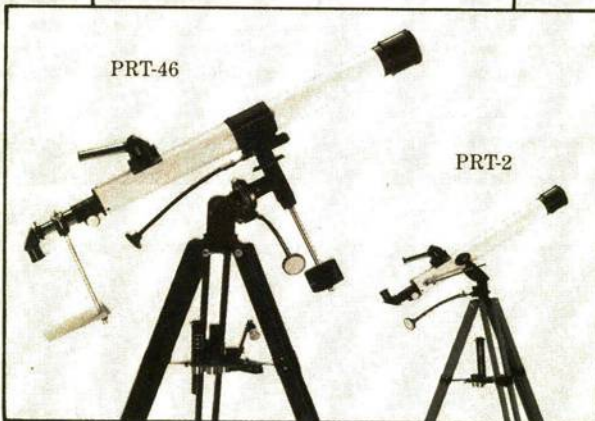
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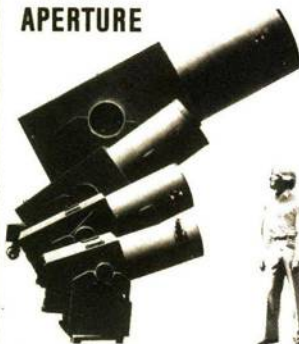
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The current discovery that extended halos surround elliptical as well as spiral galaxies strengthens the idea that hidden matter may be contained in all galaxies. More importantly, the ability to map the shape and structure of the halos

through their associated X-ray emission allows the first direct measurements of the distribution of underlying mass in elliptical galaxies. Similar techniques are being used to measure the overall distribution of mass in clusters of galaxies.

In addition, the hot X-ray emitting

gas provides insight on interactions of clusters of galaxies and their members. In studies of the relatively nearby Virgo cluster, Forman, Jones, and Tucker found examples of the outer layers of galactic coronas — the hot gas — being stripped away as galaxies move through the dense central region of the cluster.

ASTRO CALENDAR

June 28-July 1

Royal Astronomical Society of Canada General Assembly, Edmonton, Alberta, Canada. Contact: RASC, Edmonton Centre, c/o Edmonton Space Sciences Centre, 11211 - 142 St., Edmonton, Alberta, Canada T5M 4A1.

July 11-14

The Study of Variable Stars Using Small Telescopes (symposium), University of Toronto, Toronto, Ontario. Contact: Dr. John R. Percy, Department of Astronomy, University of Toronto, Toronto, Ontario, Canada M5S 1A1.

July 12-14

The Convention of the Mid-States Region of the Astronomical League, Wichita, Kansas. Contact: Mike Kittrell, c/o Crown Products Inc., 310 N. Wabash, Wichita, KS 67214. Phone (316) 267-1051 days or (316) 524-8392 evenings.

July 15-20

Spaceweek UPstate 85, Haywood Mall, Greenville, South Carolina. Contact: PAS, P.O. Box 197, Fair Play, SC 29643-0197.

July 15-24

International Space Week '85, Cocoa, Florida. Contact: James B. Harris, Jr., Director, Florida Spaceweek Committee, 993 Macco Rd., Cocoa, FL 32927.

July 15-August 2

Astronomy Institute for Pre-College Teachers, The University of Texas at Austin, Austin, Texas. Contact: Mary Kay Hemenway, College of Natural Sciences, The University of Texas at Austin, Astronomy Department, RLM 15.308, Austin, TX 78712. Phone (512) 471-4461 ext. 307.

July 18-21

The Annual Convention of the North West Region Astronomical League, Spokane, Washington. Contact: Vern Slichter, W. 10903 19th St., Spokane, WA 99212.

July 22-26

1985 Summer Institute, sponsored by Spitz Space Systems, Inc. Contact: Mona E. Coldiron, 1985 Summer Institute, Spitz Space Systems, Inc., P.O. Box 198, Chadds Ford, PA 19317.

August 9-11

STARFEST '85, The River Place Campground, Mount Forest, Ontario, Canada. Contact: Andreas Gada, 145 St. George St., Apt. 701, Toronto, Ontario, Canada M5R 2M1.

August 15-16

The New Vision of the Universe (international astronomical symposium), Medellin, Colombia. Contact: Kevin P. Marshall, ACAFA, Calle 56, N°47-23, Apto. 601, Medellin, Colombia, South America.

August 15-17

Mountain States Star Party, Monte Cristo Campground (40 miles east of Ogden), Utah. Contact: Bob Tillotson, 2336 W. 5650 South, Roy, UT 84067, phone (801) 773-8106 or Dennis Donnelly, 56 Tulane, Pocatello, ID 83201, phone (208) 232-4060.

August 15-19

Second Annual Mt. Kobau Star Party, Okanagan Valley, British Columbia, Canada. Contact: Peter Kuzel, 4100 25th Ave., Vernon, British Columbia, Canada V1T 1P4.

August 16-18

2nd Annual Mountain Astronomers Rendezvous and Star Party, Dinosaur National Monument, Northwest Colorado. Contact: Stefan C. Perrine, 7510 King St., Westminster, CO 80030.

August 17

Stellafane, Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Rd., Sudbury, MA 01776.

September 13-15

Astrofest, Chicago, Illinois. Contact: Astrofest, P.O. Box 596-A, Tinley Park, IL 60477. Phone Jon Nehls at (312) 385-3473 or John Phelps at (312) 532-2968.

September 13-15

"The Conjunction" sponsored by the Connecticut River Valley Amateur Astronomers, Northfield Mountain Environmental Center, Northfield, Massachusetts. Contact: Jack Megas, 311 Surrey Rd., Springfield, MA 01118.

September 28

Ohio Turnpike Astronomers Association Convention, The University of Akron, Akron, Ohio. Contact: Philip Hegenderfer, 5070 Manchester Rd., Akron, OH 44319. Phone (216) 644-0230.

October 5

Telescope Users Clinic, Whittier College, Whittier, California. Contact: Bob Ferguson, Western Observatory, 13215 E. Penn St., Suite 411, Whittier, CA 90602. Phone (818) 795-4181.

October 17-20

Okie-Tex Star Party, sponsored by the Oklahoma City Astronomy Club, Lake Murray, Oklahoma. Contact: Joe Pearson, 700 Teal Pl., Edmond, OK 73034.

November 7-8

SPACE STATION: Gateway to Space Manufacturing and Services, Orlando, Florida. Contact: Anne Phelan, *Space Business News*, 1401 Wilson Blvd., Suite 910, Arlington, VA 22209. Phone (703) 528-1244 or (800) 424-2908.

November 9-10

Deep South Regional Stargaze, Percy Quin State Park, McComb, Mississippi. Contact: Frank W. Loflin II, ALCOR, Jackson Astronomical Association, 280 W. Lorenz Blvd., Jackson, MS 39213. Phone (601) 982-2388 days or (601) 856-3636 evenings.

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ANNOUNCEMENT — The Birmingham (UK) Astronomical Society welcomes you to monthly meetings held the last Tuesday of each month at 19:30, Room 644, Aston University. Lectures, workshop, library, newsletter, and observing at Wast Hills site. Contact John Spittle, 28 Milverton Rd., Knowle (WM) B93 0HY or phone (0564-5) 3422.

ANNOUNCEMENT — The Astronomical Society of Kansas City meets the fourth Saturday of each month. Meetings begin at 7:30 p.m. in Room 103 of Royall Hall at the UMKC campus (Royall Hall is located between Rockhill Rd. and Holmes on 52nd St.). For more information, contact the ASKC, P.O. Box 400, Blue Springs, MO 64015, or phone Gary Pittman at (816) 228-4238.

ANNOUNCEMENT — Attention New York and Long Island stargazers! The Amateur Observers' Society of New York meets the first Sunday of each month at the Vanderbilt Planetarium, Centerport, New York. We always have plenty of room for beginners. For details, phone Barry at (516) 541-1690 evenings.

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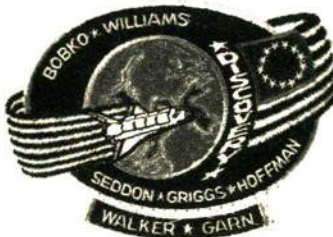
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The Rise and Fall of the Early Reducing Atmosphere

by
Stephen L. Gillett

"The origin of life is obscure, but it probably evolved under a primitive reducing atmosphere of methane and ammonia, where organic compounds were synthesized by solar ultraviolet light or lightning."

Statements like this abounded in geology and astronomy textbooks written during the 1960s and early 1970s; you can still read similar statements in popular science literature today. The "early reducing atmosphere" became conventional wisdom among most people interested in planetary science — lay enthusiasts, science fiction writers, and even many scientists whose research is unrelated to work on the early atmosphere.

But among planetary scientists, the hypothesis has become increasingly discredited. What happened?

The rise and fall of the early reducing atmosphere is a case study on how scientific ideas are proposed, tested, and revised. It is also a fascinating story that involves people, ideas, events, and shifting perceptions of the solar system's early history.

Since *reducing* and *oxidizing* are terms we'll be using a lot, before we get too deep into the story, let's detour back through Chem 101 for a refresher for those of you who dozed through the course the first time. For our somewhat simplified purposes here, you can think of an oxidizing environment as one in which oxygen dominates the tendency of elements to form chemical compounds. An example is the present-day surface of the Earth. A reducing environment is the opposite: it's dominated by elements, like hydrogen, that combine readily with oxygen. Jupiter, for example, has an extreme reducing environment.

Whenever oxidizing elements dominate, reducing material tends to be destroyed. (Rusty Jones has built a business by staving off — for a while, at least — iron's propensity to combine with oxygen.) Conversely, where reducing compounds such as methane (carbon and hydrogen) and ammonia (nitrogen and hydrogen) overwhelmingly dominate, there is no free oxygen

left because it becomes tightly bound up in compounds.

Hydrogen is by far the most abundant element in the solar system, thus the fundamental chemical environment of raw solar system material is strongly reducing. We see this not only in the outer planets, which have vast hydrogen-rich atmospheres, but also in meteorites. Many of these are solid pieces of primitive solar system material left over after the growing Sun boiled out their volatile material. Meteorites commonly contain minerals (such as metallic iron) that are much more chemically reduced than those typically found at the Earth's surface.

In the early 1950s, planetary scientist and physical chemist Harold Urey proposed that Earth's earliest atmosphere was heavily reducing. He based this idea on the abundance of elements in the solar system and on the laws of chemistry.

Urey proposed that in the waning stages of planetary accretion (the slam-bang process by which planets grew in size by swallowing up smaller bodies), when the Earth had almost attained its present size, comet-like objects rich in ice, carbon, frozen ammonia, and methane collided with the Earth, bringing in chemically-reduced material. Urey was one of the first to propose that gigantic meteorite impacts played a major role in shaping the early solar system. He pointed to the Moon as evidence of such impacts, suggesting that its many craters were the scars of those long-past collisions.

At the time, the idea was considered somewhat unusual; over the years, however, subsequent findings generally supported Urey. Examination of the Moon rocks from Apollo seems to indicate an extensive bombardment by gigantic asteroid-like or comet-like bodies that continued for several hundred million years after the Moon had essentially formed. This is now called the "late heavy bombardment" — accretion's last gasp.

This bombardment also must have hit the Earth. As these volatile-rich bodies slammed into the early Earth, they vaporized, giving rise to a primitive atmosphere. According to Urey, this would have been a methane/ammonia/water vapor atmosphere rather like those on Jupiter and Saturn today, but warmer and with very little free hydrogen. (We have no geologic record of the late heavy bombardment on Earth because no terrestrial rocks of that age survive — Earth's active surface erased the scars long ago.)

Another influence on Urey's thinking was the chemistry of oxygen itself. As we've seen, oxygen is a highly reactive element; it should not occur abundantly in a chemically-uncombined state — but it does in our present atmosphere. This anomaly is a by-product of life through photosynthesis, and relatively advanced life at that. Given that the primitive Earth was sterile, the early atmosphere could not have contained much free oxygen — only what came from the break-up of water by solar radiation.

The clincher for an early reducing atmosphere seemed to be the famous series of experiments on the origin of life done by Urey and his student Stanley Miller in the early 1950s. These experiments showed that organic compounds typical of living things, such as amino acids, are readily synthesized in an ammonia-methane atmosphere by electric sparks or by a modest amount of ultraviolet light.

So there were good reasons for accepting the early reducing atmosphere as a working model. Unfortunately, by the time the hypothesis filtered out into popular science writing, it had acquired an aura of certitude. But even as the idea was taking root in popular literature, scientific difficulties with the original hypothesis were appearing.

About the same time that Urey and Miller were doing their experiments, geologist William Rubey addressed the Geological Society of America on "The Geologic History of Sea Water." The speech has become a classic. It was followed a few years later by a more extensive monograph on the development of the oceans and atmosphere.

In it, Rubey underscored the fact that volatile elements and compounds which make up our atmosphere and oceans (water, nitrogen, chlorides, and a few others) are present to a much greater degree on the surface of the Earth than can be accounted for by the weathering of common igneous rocks — rocks such

as granites and lavas that formed by the cooling of molten rock. Rubey called these elements and compounds "excess volatiles." (The weathering of sedimentary rocks is irrelevant to Rubey's argument because the debris making up sedimentary rocks is secondary, derived either from older sedimentary rocks or from igneous rocks.)

Rubey suggested volcanic gases as a source for the excess volatiles. Gases invariably accompany a volcanic eruption — in fact, those gases are what make some eruptions explosively hazardous. He proposed that volcanic eruptions were the source, over geologic time, of the present atmosphere and thought the process continued today on a much smaller scale. He termed it "outgassing."

This seemed eminently reasonable. After all, we see volcanoes erupting today. To most scientists, outgassing from volcanoes seemed far more reasonable than postulating that volatiles came crashing in as comets. (No scientist likes to invoke an unknown process before giving up on all known ones.)

But if the Earth's atmosphere originated by outgassing from the interior, a methane-ammonia atmosphere was most unlikely. The composition of volcanic gases is controlled by the rocks they're cooked with. Methane and ammonia simply aren't chemically stable in contact with hot rock. For example, the hydrogen in methane would react with oxygen in the rock (rocks are made up mostly of oxides) to yield water. Depending on the exact conditions, the residue carbon would end up as carbon dioxide, carbon monoxide, or even as free carbon.

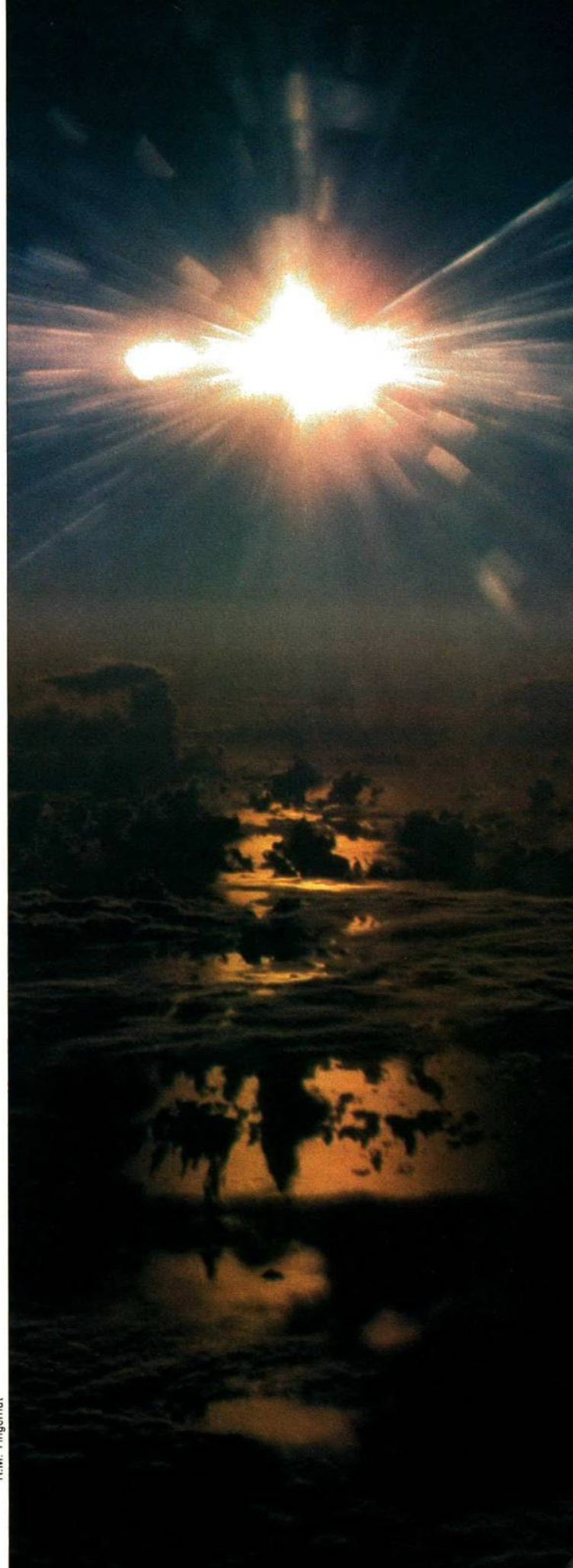
Urey, like any good chemist, was aware of such objections and suggested two possible alternatives. Perhaps, he argued, the primordial methane-ammonia atmosphere never reacted much with crustal or mantle rock because it remained on the outside of the Earth. But this seemed hard to swallow, because massive comet impacts will thoroughly stir up any rock they hit, giving plenty of opportunity for chemical reactions. Alternatively, Urey suggested that outgassing may have occurred before Earth's supply of nickel-iron separated from its constituent rocks to form the core. Before this happened, the nickel-iron may have mixed homogeneously with the rock that formed the rest of the Earth. Since nickel-iron is much more reducing than ordinary rock, volcanic gases in contact with it could stay sufficiently reduced to contain methane and ammonia and carry them to the surface.

Meanwhile, additional evidence for outgassing came to light through the work of Harrison Brown, a geochemist at Caltech in the early 1950s. His evidence was the atmospheric abundance of noble gases — elements that are almost chemically unreactive. The first three members of this group are the familiar gases helium, neon, and argon. All are rare in Earth's atmosphere; argon is the most abundant, amounting to about 1% of the atmosphere.

The argon abundance is crucial to the outgassing theory. One isotope of argon, argon-40, forms from the radioactive decay of a very long-lived, naturally-occurring isotope of potassium, potassium-40. Over 99% of the argon in Earth's atmosphere is argon-40. This argon isotope formed from the decay of potassium-40 in the Earth and worked its way to the surface. From the total amount of argon in the atmosphere, planetary scientists can estimate the degree of outgassing in the outer part of the Earth — and it has been substantial.

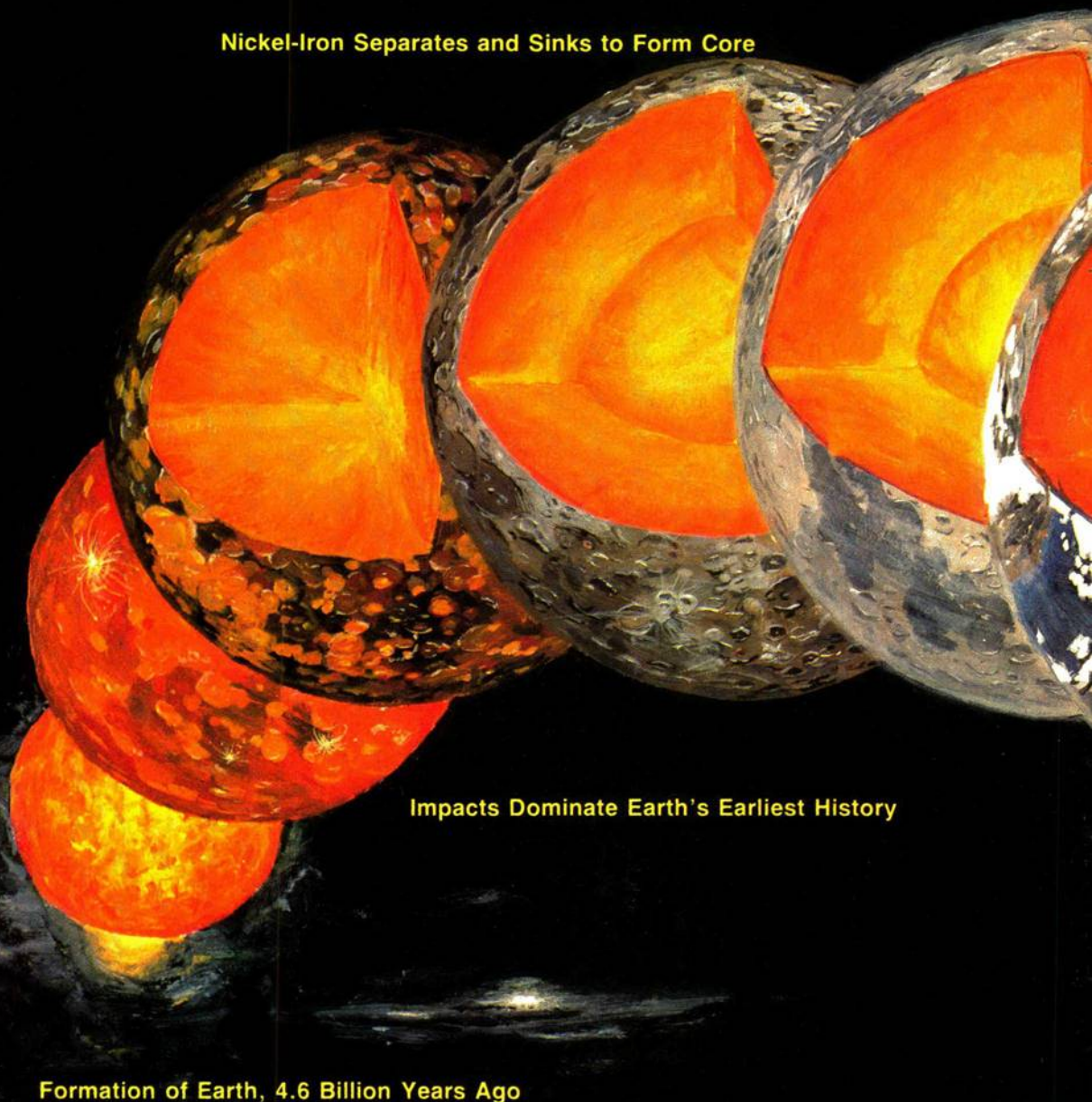
Why couldn't an early reducing atmosphere be left over from the solar nebula out of which the planets condensed and accreted? After all, this is where the hydrogen-rich atmospheres of the outer planets originated. (Such an atmosphere is called a primary atmosphere because it forms with the planet itself.) Why did Urey feel he had to postulate an atmosphere brought in by the impact of volatile-rich, comet-like bodies?

The reason is that Brown's work on noble gas abundances indicated that the present atmosphere could not have evolved from a primary atmosphere. Neon and helium are exceedingly rare in Earth's atmosphere. Looking elsewhere in the universe, these elements are quite common: Helium is the second most abundant element after hydrogen. Neon is almost as abundant as oxygen in the solar system as a whole.



R.M. Fingerhut

Nickel-Iron Separates and Sinks to Form Core



Impacts Dominate Earth's Earliest History

Formation of Earth, 4.6 Billion Years Ago

We can easily account for the scarcity of helium — the element is so light that Earth's gravity can't retain it and it continually escapes into space. Neon, however, is easily retained by Earth's gravity: it's a little heavier than water vapor. Hence, if the present atmosphere developed directly from the primary atmosphere, neon should be one of its major constituents — it isn't. Therefore, the atmosphere we are breathing cannot have come from a primary atmosphere. It *has* to be secondary, formed after the solar nebula dispersed.

This is how matters stood by the early 1960s. It was clear that Earth's atmosphere originated from some sort of secondary atmosphere, but the formation mechanism — and even the composition — of that early atmosphere were in dispute. Then, with the revolution in planetary science that followed the surge in space exploration and the discovery of plate tectonics which vastly changed our perception of the Earth, new developments

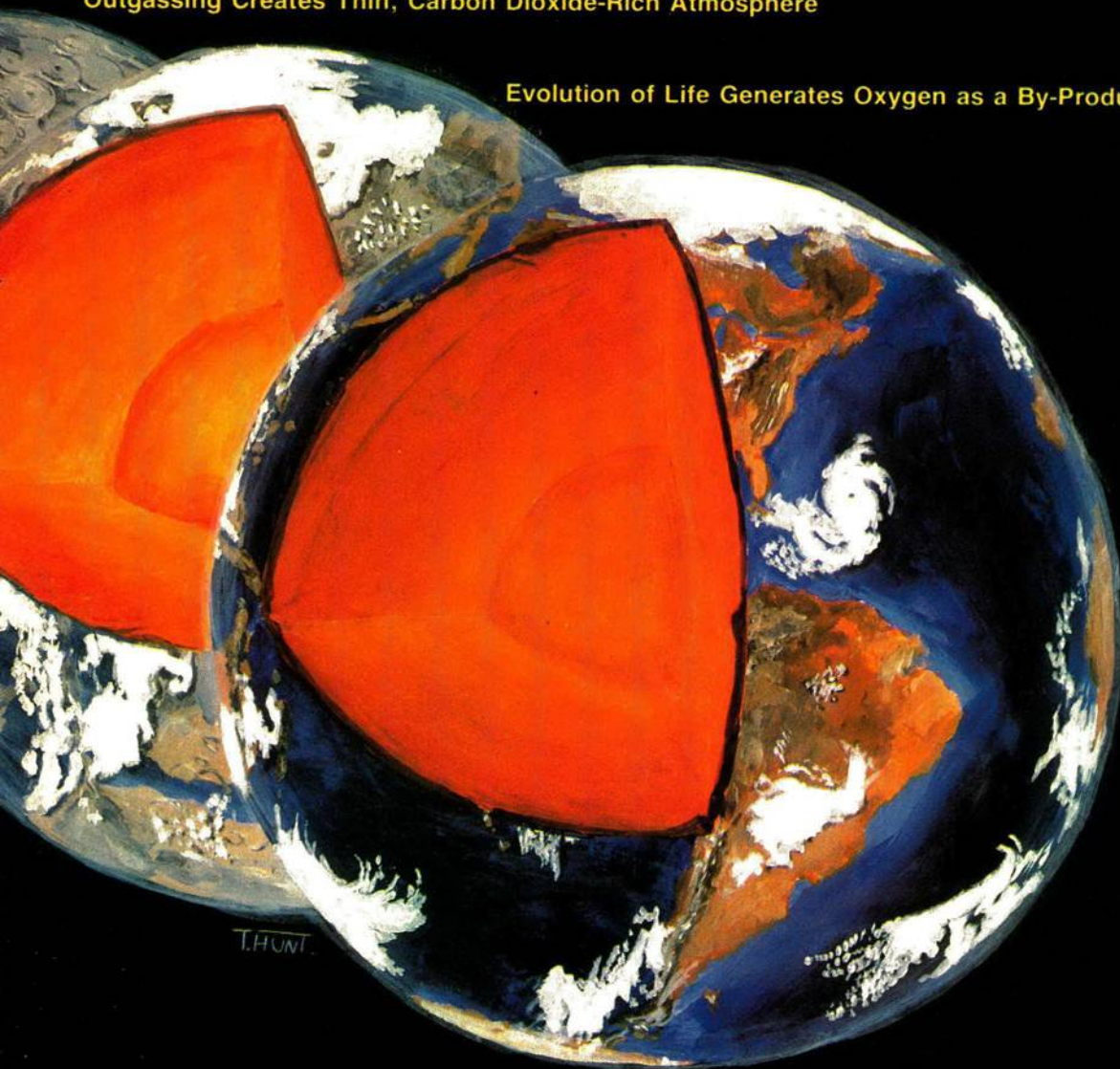
came to bear on the origin and composition of the early atmosphere.

A compelling objection to the methane-ammonia early atmosphere emerged from the research of several atmospheric scientists, particularly Joel Levine at NASA's Langley Research Center. He showed that a methane-ammonia primitive atmosphere is unstable under the Sun's ultraviolet light. Both ammonia and methane are easily broken up by ultraviolet light, and the hydrogen released would escape. Such an atmosphere would decompose rapidly: perhaps in a matter of weeks and certainly within a few thousand years — just a wink of the eye on the geologic time scale.

Next, the composition of volcanic gases — Rubey's example of outgassing today — is no longer such a major issue. Plate tectonics continually recycles volatiles back into the Earth. Sea water containing some dissolved air is carried down in

Outgassing Creates Thin, Carbon Dioxide-Rich Atmosphere

Evolution of Life Generates Oxygen as a By-Product



Today's Atmosphere: Rich in Nitrogen, Oxygen, and Water Vapor

Painting by Thomas L. Hunt

subduction zones into the Earth's mantle where it reacts with the rocks there. The volatiles later reappear in volcanic eruptions. At the moment, no one can say how much of the gas exhaled from a volcano is reaching the surface for the first time, and how much is making its second or third trip.

Plate tectonics also demonstrates that it's impossible to isolate the atmosphere and ocean from extensive reactions with Earth itself. Even if an early methane-ammonia atmosphere somehow survived the onslaught of ultraviolet light, it would soon be destroyed once the churning plate tectonics "machine" stirred it in with the crustal rocks.

Space probes have taken close-up photos of the other terrestrial planets and the Apollo missions returned rock samples from the Moon. These document the profound importance of major meteorite impacts in the history of the solar system. Mercury and Mars, as well as the Moon, are heavily cratered.

The late heavy bombardment affected all the planets.

Paradoxically, with this knowledge Urey's old idea — that the excess volatiles were plastered on by bombardment rather than outgassed — has taken on new life. But given the realization that Earth's crust is continually reworked by plate tectonics, Rubey's arguments about chemical equilibrium of crustal rocks with the atmosphere are also still sound.

What, then, was the Earth's early atmosphere like? According to Levine, "a more mildly reducing atmosphere of CO_2 and N_2 [carbon dioxide and nitrogen] is favored by photochemical considerations." This is the same general composition Rubey proposed in 1955.

Let's look at what the geologic record shows as evidence for atmosphere composition. Much chemical interaction occurs between an atmosphere and rocks at a planet's surface; such reactions should leave traces in the geologic record.

The Evolution of an Atmosphere

Urey's Model (1952)

Cold accretion of Earth

➔ Element abundances follow cosmic proportions (strongly reducing)

➔ Biology evolves out of reducing environment with help of lightning and ultraviolet light

➔ Oxygen emerges as a by-product of life

Rubey's Model (1955+)

Earth accretes

➔ Reducing atmosphere stripped off early

➔ Volcanoes outgas an atmosphere much like today's, but very low in oxygen

➔ Life evolves and releases oxygen

New Synthesis (1960 - ?)

Earth accretes hot and dry

➔ Primitive reducing atmosphere quickly dissipated by solar radiation

➔ Outgassing produces an atmosphere richer than today's in carbon dioxide

➔ Excess CO₂ keeps Earth's surface warm with the "greenhouse effect," while young Sun is less luminous than today

Sun's increasing heat drives much of the CO₂ into compounds with rocks, forming limestones, dolomites, etc.

➔ Life emerges from simple compounds like formaldehyde and hydrogen cyanide, or develops in local reducing environments at the surface or in the ocean

➔ Oxygen is by-product of life

Unfortunately, although evidence from the rock record is more direct, it is somewhat ambiguous. For one thing, no terrestrial rocks older than about 3.8 billion years are known (the record holder is a banded iron formation in Greenland), whereas the planets formed around 4.6 billion years ago and the late heavy bombardment tapered off approximately 4.1 billion years ago. The earliest and most interesting part of the record is gone. Moreover, reading the geologic record of ancient rocks that still exist is not easy. Old rocks get overprinted, chemically and physically, by younger geologic events to the extent that it's not always possible, and certainly never straightforward, to unravel what happened. Finally, the Earth's surface is highly varied — particularly due to life. We must be careful not to confuse conditions that reflect a specific restricted environment with conditions on Earth as a whole. For example, although Earth's present surface is generally oxidizing, local

reducing environments (such as marshes) abound.

Given these caveats, what might we expect? With an ammonia-methane atmosphere, we should find abundant nonbiological graphite deposits in the most ancient rocks — essentially inorganic coal beds. (Graphite is a form of pure carbon; it would form ubiquitously when solar ultraviolet light broke up methane.)

But we don't see that. Instead, we find carbonate rocks: limestone (calcium carbonate) and dolomite (a calcium-magnesium carbonate). Carbonates contain oxidized rather than reduced carbon and form by the reaction of carbon dioxide with certain oxides. This suggests that carbon dioxide rather than methane was important in the ancient atmosphere — as indeed it is today. In fact, most of the Earth's carbon, even at present, is tied up as carbonates in limestone and dolomite. Although plants make reduced carbon compounds through photosynthesis

— and all life requires such compounds — only a small percentage of the Earth's carbon is involved.

What about ammonia? Ammonia is highly soluble in water; finding a smidgen in the atmosphere means you must have a lot of it nearby in a water solution. This would have major consequences for sea water chemistry. When ammonia dissolves, the resulting solution is strongly basic (as opposed to acidic). An ocean of such stuff would react profoundly with many common types of rock.

We don't see any record of that, either. Having nitrogen present as a free element — rather than combined in ammonia — agrees much better with the geologic record. Free nitrogen hardly reacts at all with common rocks.

So an early atmosphere consisting mainly of CO₂ and N₂ is consistent with the geologic record — that is, since about 3.8 billion years ago.

Of course, we would still expect the primitive atmosphere to be devoid of all but traces of free oxygen. Yet even this conclusion is difficult to verify from the geologic record. A nonbiological source of oxygen is the photodissociation of water. Water isn't as vulnerable to photodissociation as are methane and ammonia because its freezing point is higher. Most water vapor freezes in the upper atmosphere before it rises high enough to be destroyed.

Nonetheless, the oxygen from photodissociated water is significant, and we now have an astronomical example: The results from chemical experiments on the Viking landers — although still ambiguous — show the martian surface is very highly oxidized. In addition, the planet's red color seems to be due to ferric (iron) oxide. Although Mars hasn't accumulated much oxygen in its atmosphere, its surface is highly oxidized — perhaps resulting from a time when the planet's climate was far wetter.

Scientists find it difficult to infer the history of oxygen build-up in the Earth's atmosphere from the geologic record. It's hard to distinguish the presence of a small amount of oxygen resulting from photodissociation from a larger amount of oxygen resulting from later photosynthesis. Either way, surface rocks came out oxidized. Geologic evidence for an early oxygen-free or oxygen-poor atmosphere is annoyingly ambiguous. For example, it is commonly accepted that banded iron formations — such as the 3.8 billion-year-old rocks in Greenland — formed when the Earth's atmosphere was oxygen-poor, while red beds — strata stained red with hematite or ferric oxide — started to form about 2 billion years ago when oxygen began appearing. This suggestion was originally made by Preston Cloud at the University of California.

But the picture now seems oversimplified. For one thing, banded iron formations are a mixed lot indeed. To label them with one name is like lumping together a red Ferrari, a red Volkswagen, and a fire engine — all because they're red. These rocks probably have different origins and reflect different environmental conditions. Furthermore, some extremely old red beds have been found, which casts doubt on the either/or idea of red beds picking up where banded iron formations leave off.

The significance of red beds themselves has also been questioned. Theodore Walker and his students at the University of Colorado in Boulder have shown that at least some form gradually over geologic time by the slow oxidation of iron minerals by oxygenated groundwater — a process that may take millions of years. Such a red bed might not tell us anything about the amount of early atmospheric oxygen, since the oxidation causing the reddening could be hundreds of millions of years younger than the rocks themselves.

One piece of evidence for an early oxygen-poor atmosphere is that fragments of certain minerals, easily oxidized and destroyed in Earth's present atmosphere, are found preserved in some ancient sedimentary rocks. But this evidence isn't compelling, either. First, we see such minerals preserved today in desert and polar region sediments. The paradox is explainable by the fact that in these environments, chemical weathering proceeds very sluggishly. And once again, since the surface of

the Earth is diverse, we must be careful not to confuse particular environments with conditions typical of the Earth as a whole.

Second, in such ancient sedimentary rocks, it is difficult to tell the minerals which were original fragments from those which later grew in place due to changing chemical conditions within the rock. Such changes in the chemistry and texture of rocks are found everywhere. The study of such changes, called diagenesis, is a major branch of sedimentary geology.

A lesson taught over and over by the Earth is that very old rocks have experienced many events, and it's often difficult or impossible to sort out what's transpired. Overall, the relation between atmospheric oxygen and surface oxidation is very unclear. It's frustrating, because although we see no evidence of strongly reducing conditions in the geologic record, Mars shows us that very small quantities of nonbiological oxygen can cause major surface oxidation.

The point at which oxygen began to build up also has implications for the ozone layer. Because ozone is an unstable form of oxygen, and because it plays a major role in shielding the Earth's surface from the Sun's hard ultraviolet radiation, scientists generally think that life in surface water and on land couldn't exist until oxygen built up to the point where a shielding ozone layer could form. It's uncertain, however, how much oxygen in the lower atmosphere is needed to form an ozone layer high above the ground. If some oxygen were already present from photodissociation, the ozone layer may be quite ancient.

And what about life itself? If the early reducing atmosphere, which the Urey-Miller experiment was so successful with, never existed on a global scale — where did life come from? Firstly, reducing environments must have occurred at a local level on primitive Earth just as they do on modern Earth, regardless of the overall chemical environment. Secondly, researchers have found that compounds simpler than amino acids could lead to life through a slightly less direct route — for example, by means of formaldehyde and hydrogen cyanide. Formaldehyde results when you spark a mixture of nitrogen, carbon monoxide, and water — all elements now thought present in the early atmosphere. Hydrogen cyanide is more complicated to make, but not impossible. Lastly, recent oceanographic research has uncovered hot vents (called "black smokers") on the ocean floor where methane and ammonia are being produced when sea water reacts with hot volcanic rock.

In short there seem to be plenty of alternatives for creating life, and the lack of an early reducing atmosphere doesn't mean life couldn't have formed! In fact, given the existence of black smokers, the role of the atmosphere itself may need revising, since it's entirely possible that the first chemical steps toward life began deep in the oceans.

For all the effort that's been expended on the problem, the conclusions reached by scientists on the origin and nature of Earth's early atmosphere are distressingly few. The discovery of plate tectonics invalidated Rubey's assumption that gas coming out of volcanoes was reaching the surface for the first time. It also established that any early terrestrial atmosphere had to react extensively with the Earth's crust and mantle, which spelled trouble for Urey's idea of a primitive methane-ammonia atmosphere. A new tentative hypothesis has emerged, incorporating elements from both: Volatiles probably came in with the late heavy bombardment, as Urey thought, but the resulting atmosphere reflects extensive chemical reactions with the solid Earth, as Rubey thought. Furthermore, there are wrinkles in the new model not anticipated previously, like the "regassing" of Earth's crust and mantle plate tectonics.

Is the story complete? Hardly! In fact, there are planetary scientists who disagree with this version right now. No one anticipates that this model is the last word — yet at least the ground rules are becoming clearer.

Stephen Gillette is a consulting geologist in Seattle. His last feature in ASTRONOMY was the two-part article "Possible Planets" in the January and February 1984 issues.

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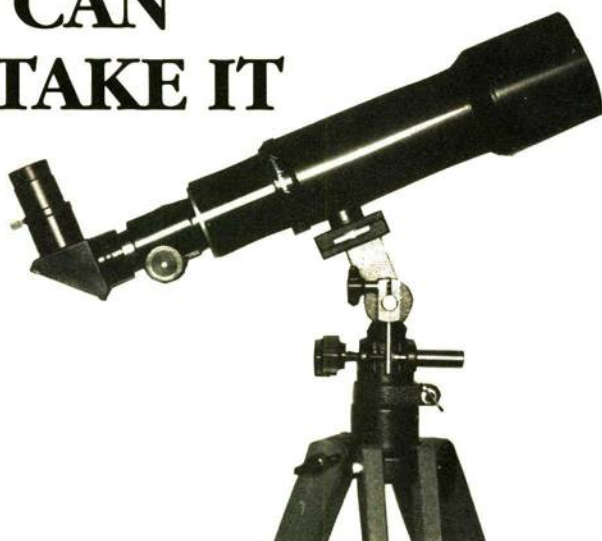
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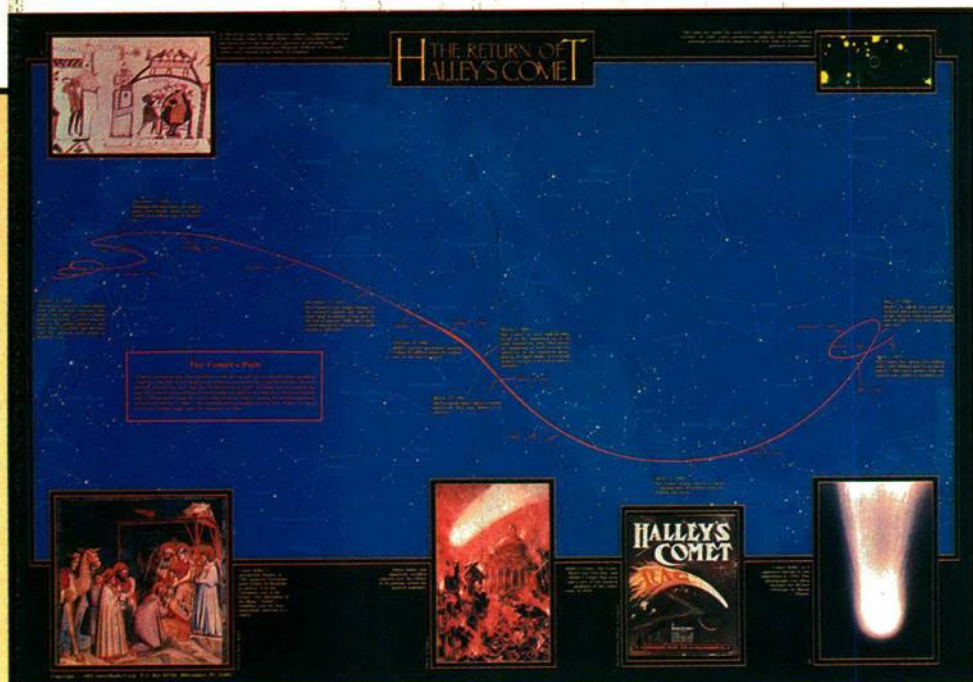
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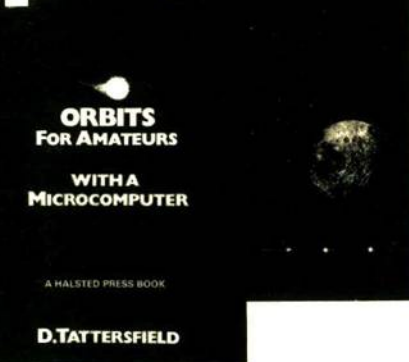
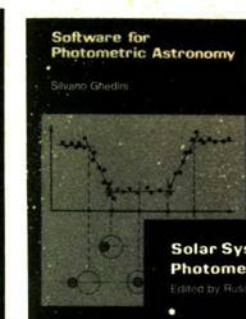
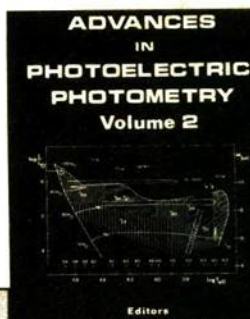
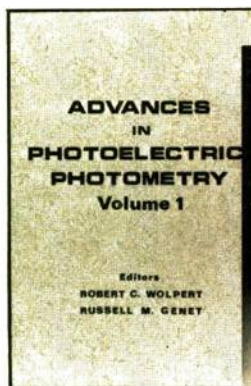
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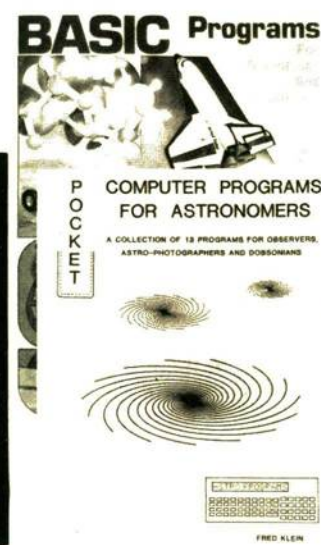
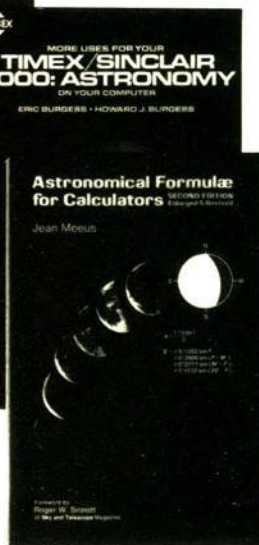
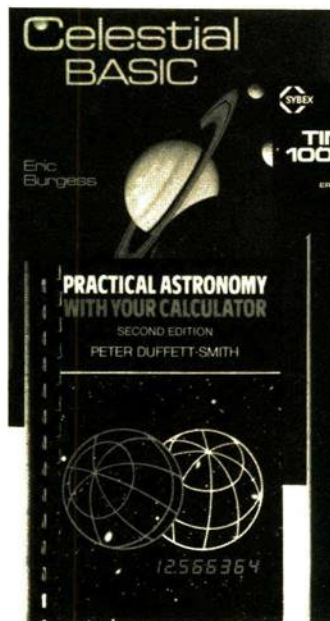
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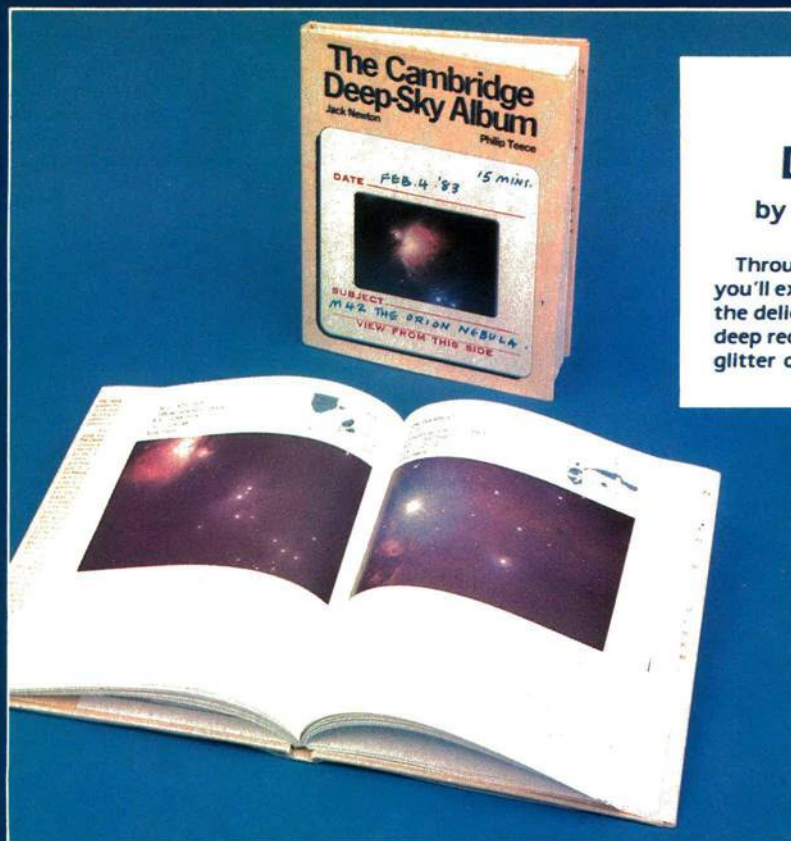
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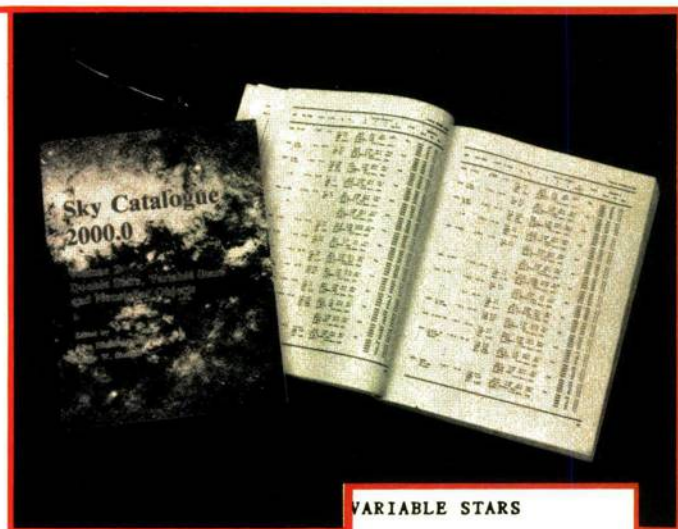
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Left: NGC-6791, an exceedingly rich open cluster, is visible in binoculars on dark nights. Photo by Martin C. Germano. Above left: Often overlooked, globular M-56 shines at eighth magnitude and spans over 7' across. Photo by Al Ernst. Above: The Ring Nebula, M-57, is the most observed planetary nebula in the sky. Photo by John P. Gleason.

Lyra

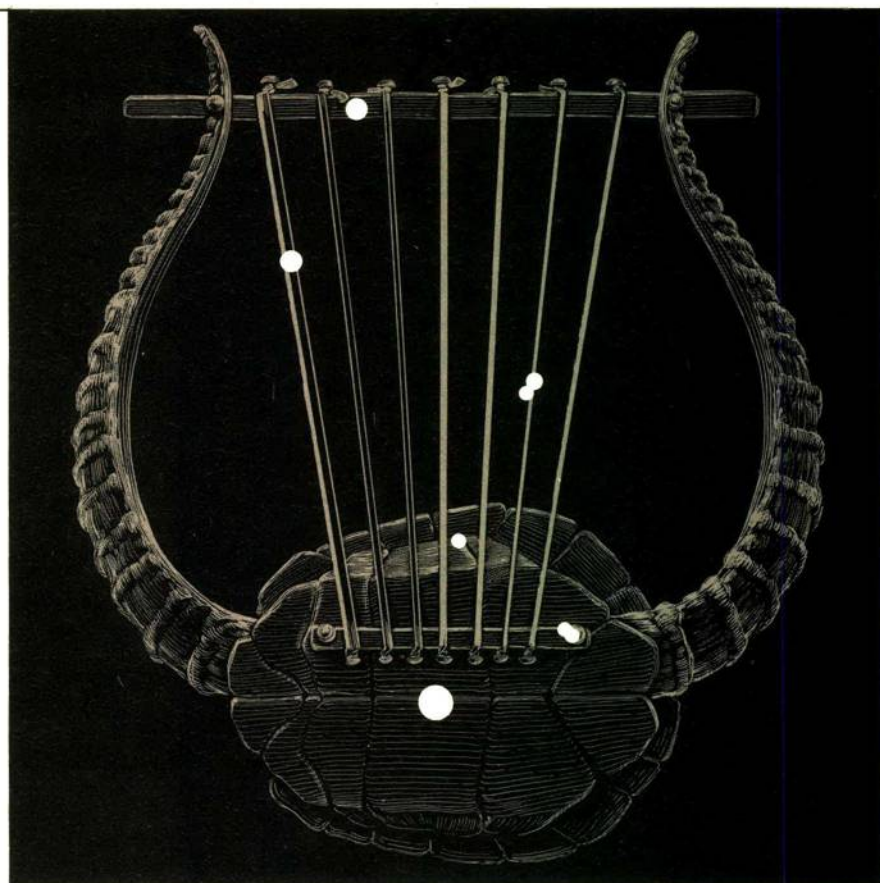
Lyr
Lyrae

Lying between the constellations Cygnus and Hercules in the northern summer Milky Way is the petite but bright grouping of stars **Lyra** the Lyre. Although one of the smallest constellations in this part of sky, this very distinctive group lies in a direction where many unusual stars, nebulae, and even a few galaxies reside.

The most observed object in Lyra is the planetary nebula **Messier 57**, popularly known as the Ring Nebula. Measuring some 70" across and glowing at magnitude 8.8, M-57 is a small but easily recognizable "smoke ring" of hazy light in even a 3-inch refractor. A 6-inch telescope operating at high power clearly shows the central dark hole, which is actually the thinnest part of a spheroidal shell of gas, but M-57 appears as a ring because we see only the thickest areas of nebulosity. A good 8-inch scope shows M-57 as distinctly elliptical with a faint star just off its eastern edge.

The visibility of M-57's central star, a tiny bluish dwarf weakly glowing at about 15th magnitude, is the subject of much debate. Curiously, several observers have reported seeing this faint speck inside the Ring using telescopes as small as 5 inches aperture. Then again, others have failed to spot it with telescopes in the 24 to 40-inch range! What is the explanation for this apparent discrepancy? The star may be variable, or — since it is enveloped in nebulosity — extremely sensitive to observing conditions.

Unknown to many observers is a second planetary nebula in Lyra, **NGC-6765**. This object is much fainter than the Ring and measures some 38" across — about half as much as M-57. This planetary's central star is a 16th magnitude object, so don't expect to have an easy time spotting it. Try looking for NGC-6765 with a large, low-power telescope; if you find it, you'll be among a select group of



Keith Ward

observers to do so.

One of many fascinating stars in Lyra is the constellation's brightest, **Vega** (Alpha [α] Lyrae). At magnitude 0.04, Vega is the fifth most luminous star in the sky; along with Deneb in Cygnus and Altair in Aquila, it is recognizable as a member of the so-called Summer Triangle. Lying at a distance of 8.3 parsecs, Vega is a type A0 main sequence star with a surface temperature of 9200 Kelvins — nearly twice as hot as the Sun. Vega has a 10th magnitude bluish companion located some 1' away in position angle 173°; the two stars are not physically connected but happen to lie along the same line of sight.

Another notable star in Lyra is **Sheliak** (Beta [β] Lyrae), the prototypical eclipsing binary star. At maximum, Sheliak is a magnitude 3.4 brilliant blue-white star with a spectral type of B8; it lies just under 300 parsecs away. Sheliak regularly varies in brightness from about magnitude 3.4 down to 3.8 or 4.1 at alternate minima. This variation is due to mutual eclipses of two stars in the system; the period is 12.91 days.

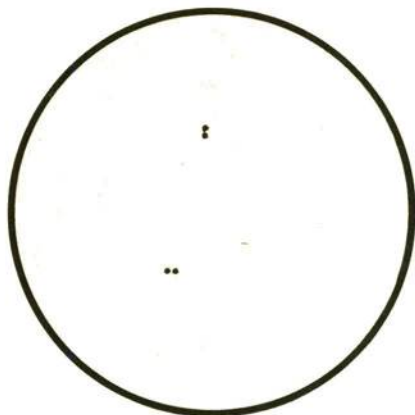
You can observe Sheliak's regular dimming and brightening by comparing its magnitude — over a period of around two weeks — to equally bright surrounding stars. Make a sketch of the field using binoculars or a small wide-field telescope; given enough time, you'll spot a pattern of changing brightness.

One of the finest double stars for small scopes is **Delta (δ) Lyrae** whose magnitude 4.5 and 5.5 components are separated by a whopping 10½ arc-minutes. Despite their great separation and a distance from Earth of about 250 parsecs, the two stars seem to be traveling through space together. They are best observed with binoculars, and form a beautiful color contrast of bluish-white and ruddy orange. A number of other bright stars lie in this same field, and they probably form a physical cluster which includes the Delta Lyr system. If so, this is one of the closest open star clusters to Earth.

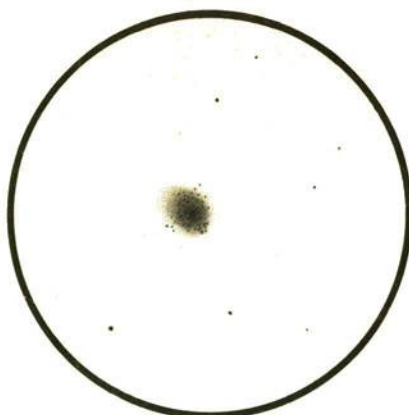
One of Lyra's stately variable stars is **R Lyrae**, a so-called semi-regular variable in the northern part of the constellation. Over a period of about 46 days, this star slowly and fairly regularly varies between magnitudes 4.1 and 5.0. As are most stars of this type, R Lyr is a reddish star of spectral type M6; this poses a problem in observing it because of the Purkinje effect — the retina's oversensitivity to red light. So when viewing this and other red stars, take quick glances rather than lengthy stares.

Not to be confused with R Lyr is the short-period star **RR Lyrae**, located a few degrees eastward. This is the prototype "cluster variable," so named because many of these stars are found in globular clusters. RR Lyrae itself has a period of

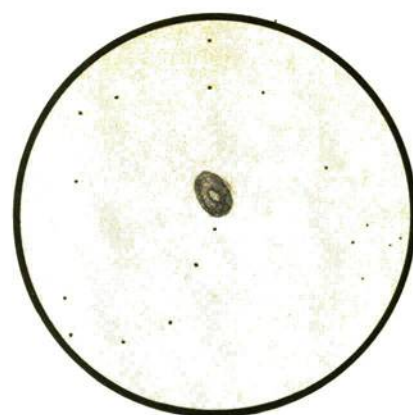
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Sketch by Glenn F. Chaple



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0.567 day, and a magnitude range between 7.1 and 8.0.

The finest multiple star in the area is **Epsilon^{1,2} (ε)** **Lyrae**, better known as the "Double-Double." Lying about 1½° east of Vega, Epsilon Lyr appears as a double star in binoculars or to those with very sharp eyesight; when viewed with a medium-power telescope, each star transforms into a double in its own right, making the system quadruple. The two main systems of stars are separated by some 208". Epsilon¹ is composed of magnitude 5.5 and 6.5 stars, separated by 2.8" in position angle 359°, while Epsilon² is made up of magnitude 5 and 5.5 stars separated by 2.2" in p.a. 98°. The ability to split these stars using a small telescope serves as a good indicator of steady seeing on any given night.

The southern part of Lyra holds the unusual star **HR Lyrae**, dimly glowing at about 15th magnitude. In 1919, it

brightened suddenly to magnitude 6.5 before slowly fading back to anonymity. This star is unspectacular to observe now, but is verifiably the burned-out remnant of a nova explosion that occurred nearly 70 years ago.

Toward the eastern edge of Lyra — several degrees southeast of the bright star Theta — is the unusually rich star cluster **NGC-6791**. This object measures about 16' across and contains some 300 stars — resulting in a total magnitude of 9.5. The cluster appears as a mass of fuzz in small telescopes since the brightest members are 13th magnitude objects. Large telescopes at medium powers show a rich blend of tiny stars strewn across the entire field. This cluster lies at a great distance of 5.1 kiloparsecs.

The second Messier object in Lyra is **M-56** (NGC-6779), a small but bright globular cluster with a characteristically tight core. Overshadowed by M-13 in

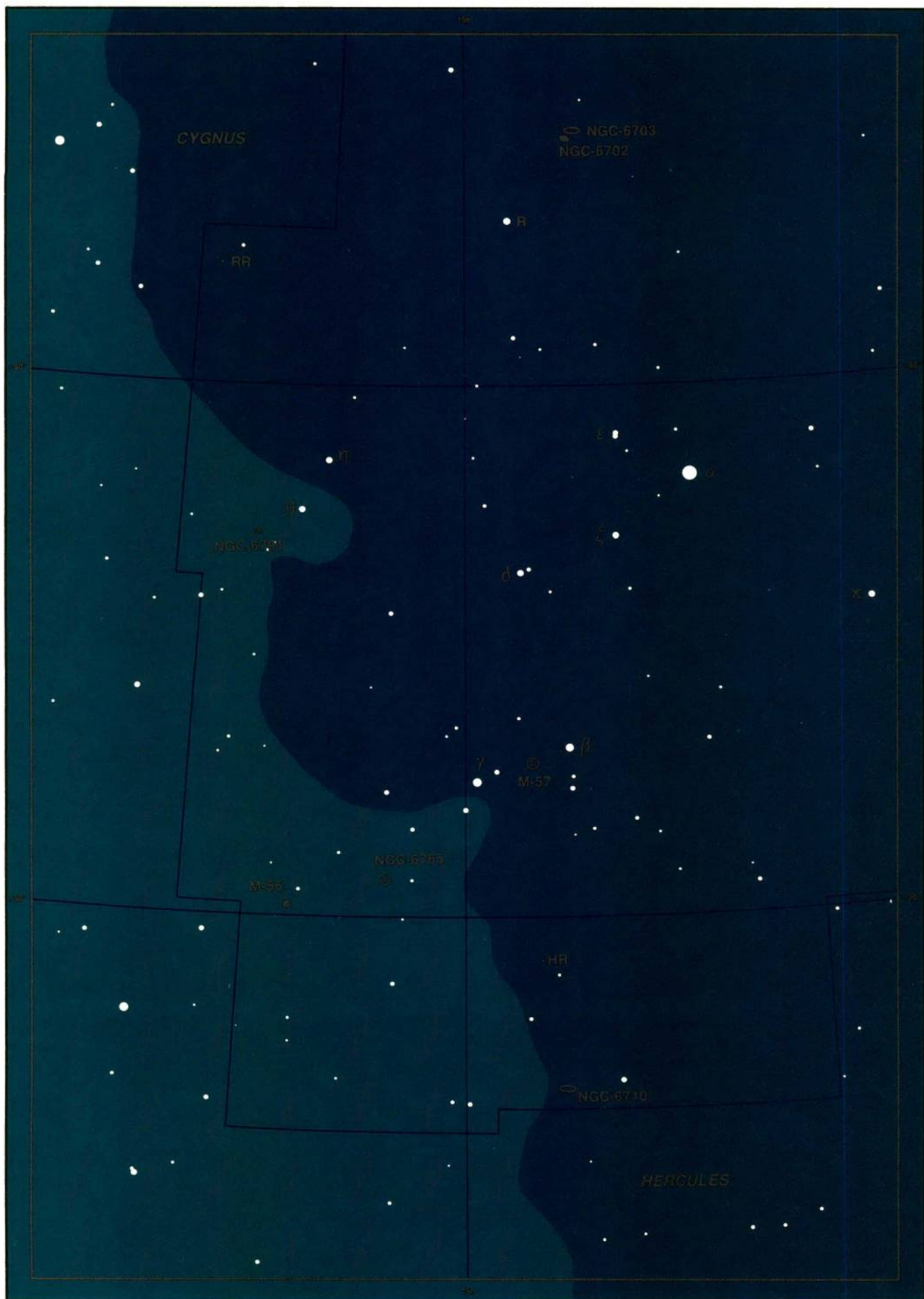
Hercules, M-56 is a fine object deserving more attention. It measures 7.1' across and shines at magnitude 8.3. Visible as a fuzzy "star" in finderscopes, M-56 appears as a glob of nebulosity in a 3-inch refractor. An 8-inch telescope doesn't resolve it, but shows a mottled edge surrounding an intensely bright core.

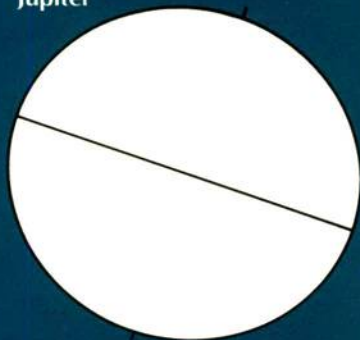
Despite Lyra's proximity to the galactic plane, it contains three notable galaxies. The first, **NGC-6703**, lies in the north-central part of the constellation: shines at magnitude 11.5, spans 2.6' x 2.5', and is a lenticular galaxy viewed nearly face on. Lying adjacent to NGC-6703 is **NGC-6702**, a slightly dimmer and smaller elliptical galaxy. Along the southern boundary of Lyra is the galaxy **NGC-6710**, a 13th magnitude lenticular measuring 2.0' x 1.2'. All three of these galaxies appear as circular or elliptical smudges with little detail in most backyard telescopes.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	H
Vega (α)	★ ²		18h 36.9m	+38°47'	0.0,10	62.8"	
Epsilon ^{1,2} (ε ^{1,2})	★ ⁴		18h 44.3m	+39°40'	5.5,6.5 5.0,5.5	2.8"x2.2"	
NGC-6702		0	18h 47.0m	+45°42'	12.2	2.1'x1.6'	E3:
NGC-6703		§L	18h 47.3m	+45°33'	11.4	2.6'x2.5'	S0
Sheliak (β)		EV	18h 50.1m	+33°22'	3.4-4.3	12.9d	
NGC-6710		§L	18h 50.6m	+26°50'	12.8	2.0'x1.2'	S0:
NGC-6720	M-57	■	18h 53.6m	+33°02'	8.8	80"x60"	
Delta (δ)		★ ²	18h 53.7m	+36°58'	5.5,4.5	10.5'	
HR		N	18h 53.7m	+29°14'	6.5-15	Irr.	
R		SRV	18h 55.3m	+43°57'	4.1-5.0	46d	
NGC-6765		■	19h 11.1m	+30°33'	—	38"	
NGC-6779	M-56	●	19h 16.6m	+30°11'	8.3	7.1'	
NGC-6791		0	19h 20.7m	+37°51'	9.5	16'	
RR		CV	19h 25.5m	+42°47'	7.1-8.0	0.57d	

H = Hubble classification type for galaxies

- ★² Double Star
- ★⁴ Quadruple Star
- EV Eclipsing Variable
- SRV Semi-Regular Variable
- CV Cluster Variable
- 0 Open Star Cluster
- Globular Star Cluster
- Planetary Nebula
- 0 Elliptical Galaxy
- §L Lenticular Galaxy



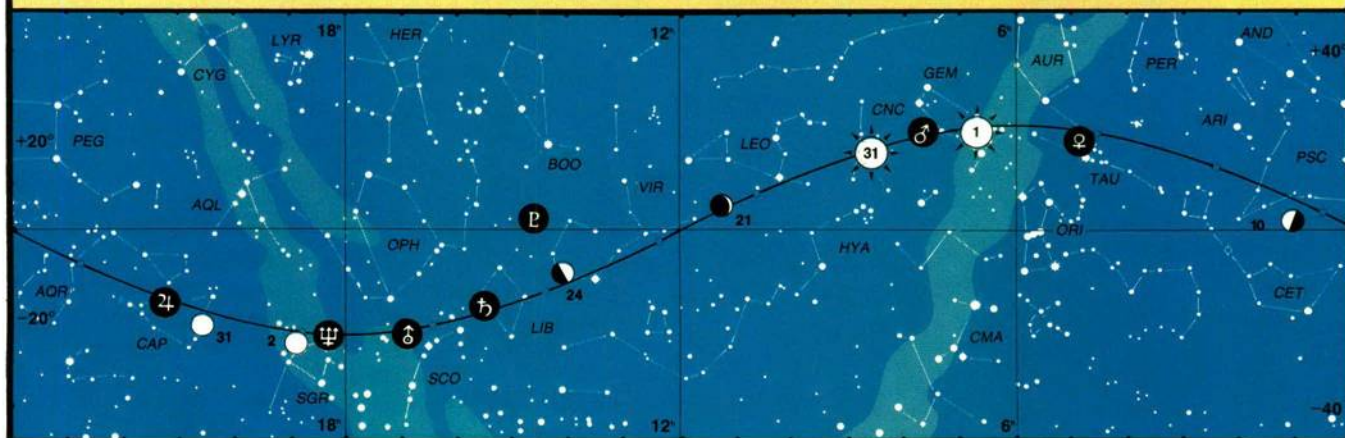


5th

15th

15th

Full Moon July 2 at 12h08m
Last Quarter July 10 at 0h49m
New Moon July 17 at 23h56m
First Quarter July 24 at 23h39m
Full Moon July 31 at 21h41m
Last Quarter August 8 at 18h29m
Apogee: July 11 at 7h41m 404,258 km.
Perigee: July 25 at 17h32m 369,645 km.



The Sun in H α on April 29, 1984. Lee Coombs made two exposures — one for the prominences and one for the disk — and double printed them. His equipment was an 80mm f/20 refractor with a 0.75 Angstrom H-alpha filter and Kodak 2415 film. The exposures were 1/60 and 1/250 second.

Mercury

In July, Mercury reaches greatest eastern elongation in the evening sky and finishes an apparition that began last month. Peak elevation — which means best telescopic viewing — comes during the first few days of July (see diagram on this page in last month's issue). Greatest elongation from the Sun, however, is on the 14th. About a week later, the planet will drop down too close to the Sun to be seen. Inferior conjunction comes on August 10th.

Venus

This month, Venus' elevation peaks in the morning sky. Now slightly more than half lit, the planet's disk will grow smaller and more gibbous, finally becoming round by the end of the year.

Since Venus still retains most of its brightness, glare is a problem for telescopic observers. Fortunately, the planet rises before the Sun; you can find it while the sky is dark, and then let the brightening dawn reduce the contrast between Venus and the sky to a more comfortable level. (And don't miss the beautiful groupings of Venus, the Moon, and Aldebaran on the mornings of the 13th and 14th — see Eye on the Sky for more details.)

Earth

Aphelion occurs on July 5th at 10h UT when we will be 1.016689 astronomical units (152,095,000 kilometers) from the Sun.

Mars

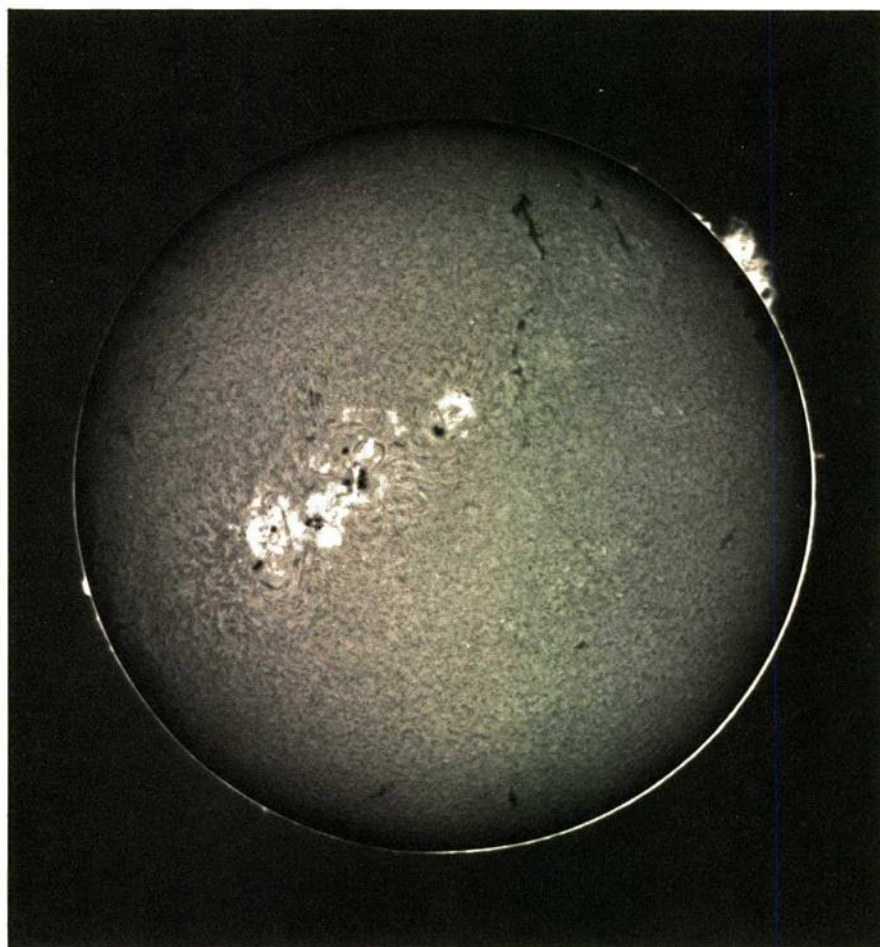
Mars is in conjunction with the Sun on July 18th; it is out of sight all month.

Minor Planets

1 Ceres was in conjunction on June 30th and is still too close to the Sun to be seen.

Universal Time

Astronomers the world over use an unambiguous system of time reckoning — Universal Time (UT) — based on a 24 hour clock. Times given in The Backyard Astronomer are UT unless noted otherwise. To convert UT into your local daylight time, subtract the following number of hours for each time zone: EDT, 4; CDT, 5; MDT, 6; PDT, 7; Alaska, 9. For example, if an event is to happen at 3h00m UT on June 7th, then EDT for the event is 11 p.m., June 6th. Likewise, 13h00m UT on September 2nd becomes, in PDT, 6 a.m., September 2nd.

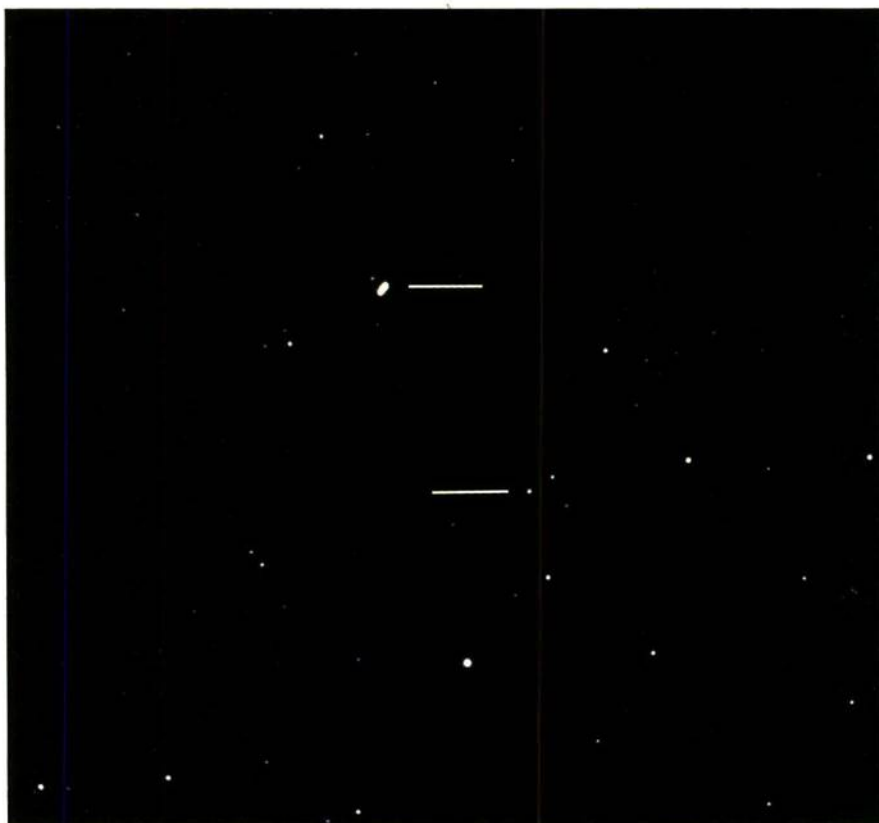


Satellites of Jupiter

2:00 UT

1	CEJG		16	CJIGE	
2	CJIGE		17	CGJ	
3	GIEJC		18	GCEJI	
4	GEJC		19	GJIE	
5	GJIEC		20	GIJEC	
6	IJGEC		21	EJIGC	
7	EJIGC		22	IEJGC	
8	IEJGC		23	JIEGC	
9	JIGEC		24	IGJEC	
10	GEJC		25	GEJIC	
11	GECJI		26	GIJC	
12	CGJE		27	GJCE	
13	CGJE		28	CEJIG	
14	CEJIG		29	CEIJG	
15	CIEJG		30	CJIEG	
			31	CIJE	

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)



Right: In August 1984, Jupiter lay near the Lagoon and Trifid Nebulae; this photo of the grouping by Henry Nebel of Alfred University wins July's "Best Astro-Photo" award. He used a 135mm f/2.8 lens (piggybacking the camera) and an 8-minute exposure on Ektachrome 400 pushed to ISO 800. Left: another grouping! The short trail (upper line) is the minor planet 3 Juno; to the southwest (lower line) is the famous quasar 3C 273. Photo by William Sorrells; 16-inch f/5, Agfachrome 1000, 10-minute exposure.

2 Pallas (magnitude 9.3) is moving eastward in northern Eridanus toward Rigel in Orion, which it will pass north of in August. Its positions:

10th: 3h 54m 53s, $-1^{\circ} 19.6'$

20th: 4h 12m 05s, $-2^{\circ} 01.4'$

Pallas rises about 4:30 a.m. local daylight time on the 15th — close enough to sunrise to make observing it difficult.

3 Juno (11.2) is in central Virgo and passing through a region littered with NGC galaxies. Its positions:

10th: 12h 26m 12s, $4^{\circ} 33.8'$

20th: 12h 34m 46s, $3^{\circ} 38.7'$

Juno sets around midnight local daylight time at mid-month.

4 Vesta (7.2) is also in Virgo, about 4° east-southeast of Zeta (ζ) Virginis. Its positions:

10th: 13h 51m 09s, $-4^{\circ} 17.4'$

20th: 14h 00m 46s, $-5^{\circ} 56.9'$

Vesta sets around 12:30 a.m. local daylight time on the 15th.

For convenience in plotting their motions on a star atlas, all minor planet positions are for the epoch 2000.0.

Jupiter

Moving westward in its retrograde loop, Jupiter will pass close to two stars in the latter half of the month. First encountered is 6.0 magnitude SAO 164156, which will be $7'$ of arc south of Jupiter at 17h46m UT on the 19th. The star will look like a tiny out-of-place Galilean moon.

The second event occurs four days later on the 23rd, when Jupiter passes $15'$ south of 4.2 magnitude Theta (θ) Capricorni at 11h04m UT. This conjunction is more distant than last April 18th's, when only $4'$ separated them. The time of closest

approach occurs at dawn (for locations west of roughly the 95th meridian) or after sunrise (east of there), but anyone observing during the night will be able to see the planet and star together perfectly well.

Jovian moon events: On July 10th between 9h34m and 9h40m UT, Callisto will partially occult Io causing a 1.2 magnitude dimming. This occurs 2.8 Jupiter radii east of the planet. On July 30th, Ganymede will partially eclipse Europa 9.0 radii east of Jupiter between 6h35m and 6h49m UT. Europa will drop 1.4 magnitudes in brightness.

Saturn

As evening twilight darkens, Saturn is the bright yellow-white object in the southern sky, roughly halfway between Spica on the west and Antares to the east. In a telescope, it displays a ball $17''$ of arc in diameter surrounded by a ring $40''$ across. If you have a night where the seeing is very good, try using high magnification and look for the planet's shadow on the rings. It lies east of Saturn's ball and will slowly increase in extent until late July — but will never become truly prominent.

Uranus

The target for a Voyager 2 flyby just six months from now, Uranus is an unusual planet. Since it orbits the Sun "on its side" — Uranus' axis tilts 98° — at times the uranian poles point toward us. At present, the center of its disk lies only 8° from Uranus' south pole.

Of its five moons (Miranda, Ariel, Umbriel, Titania, and Oberon), only Titania (magnitude 14) offers much hope

of being seen visually — and that will require a scope in the 14-inch to 17-inch class. Titania orbits counterclockwise once every 8d 17m at a distance $33''$ from the center of Uranus. It lies north of the planet on the 7th at 22h, on the 16th at 16h, and on the 25th at 10h UT.

To find the moon, observe the planet every clear night and, by hand or photography, map all objects close to Uranus down to 15th magnitude. After a few nights' observing, you ought to be able to pick out the dot that's circling Uranus.

Neptune

Neptune has two satellites: Triton and Nereid, but only the former is visible in even large backyard instruments. At magnitude 13.7 — the same as Pluto! — Triton follows a 5d 21h counterclockwise orbit. Projected on the sky, its orbit is pronouncedly elliptical with a distance from Neptune that ranges between $9.2''$ (at north and south elongations) to $16.8''$ (east and west). It lies at eastern elongation on July 6th at 2h, on the 11th at 23h, on the 17th at 20h, on the 23rd at 17h, and on the 30th at 5h. As with Titania, repeated observations and mapping should uncover the moon in a few days — if your scope has enough aperture.

Meteors

Both of July's main meteor showers are broadly diffuse: Capricornids can be seen during all of July and part of August, and Delta Aquarids run from the middle of July to the end of August.

Capricornids appear to have several days of peak activity — July 8th, July 26th, and August 2nd — with an average zenithal hourly rate of 5 to 10. Delta Aquarids have two streams: the southern peaks on July 29th and the northern peaks on August 7th. Rates differ, although the southern stream is stronger; look for about 10 to 20 meteors per hour from a dark-sky location.

Comet Halley

During July, the comet is moving eastward out of Taurus toward the upraised club of Orion. Its positions (epoch 2000.0):

10th: 5h 40m 55s, $18^{\circ} 28.3'$

20th: 5h 47m 28s, $18^{\circ} 40.6'$

Still lost in the solar glare, at mid-month Comet Halley is at magnitude 14.4 and lies 4.2 astronomical units away from Earth.



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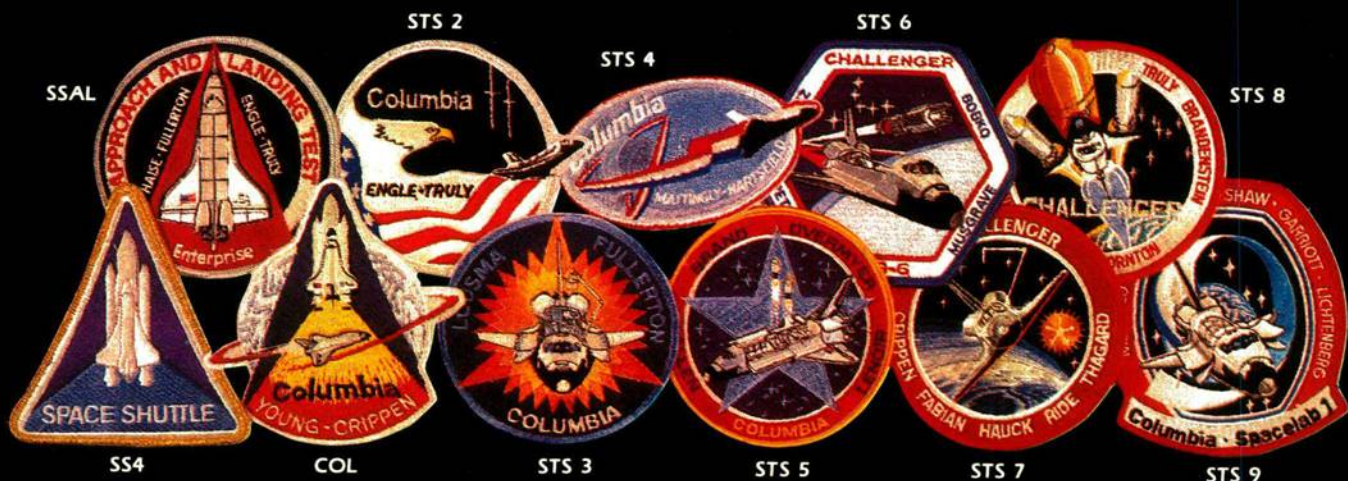
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